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BRITISH COLUMBIA
DEPARTMENT OF MINES AND PETROLEUM RESOURCES

HON. DONALD L. BROTHERS, *Minister* K. B. BLAKEY, *Deputy Minister*

BULLETIN No. 53

GEOLOGY of the AINSWORTH-KASLO AREA

BRITISH COLUMBIA

by
JAMES T. FYLES

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Geology of the Ainsworth-Kaslo Area

SUMMARY

1. The Ainsworth-Kaslo area is along the western side of Kootenay Lake 40 to 60 miles northeast of Nelson.

2. It is in the central part of the Kootenay Arc, a curving belt of complexly deformed sedimentary, volcanic, and metamorphic rocks extending from Revelstoke southeast, south, and southwest across the International Boundary. The map-area is in the northerly trending part of the arc adjacent to the eastern margin of the Nelson batholith.

3. This report is primarily a study of the structure and the structural setting of lead-zinc deposits in the Ainsworth mining camp.

4. The rocks of the area range from Lower Cambrian to Upper Triassic and include medium- and fine-grained mica schists, limestones and marbles, hornblende schists and quartzites. They are intruded by sills and lenses of fine-grained granite, granite pegmatite, the Nelson granitic batholith, and by lamprophyre sills and dykes. Details of the lithology are summarized in the legend of Figure 3 (in pocket) and tentative correlations are shown in the legend of Figure 2 (in pocket). The rocks belong to the Lardeau, Milford, Kaslo, and Slocan Groups.

5. The grade of regional metamorphism increases toward the east, from biotite near the Nelson batholith to sillimanite grade along the shore of Kootenay Lake.

6. Throughout the area the rocks, which are strongly foliated, dip at moderate angles to the west and are split by strike faults essentially parallel to the foliation.

7. In each fault slice, isoclinal folds are the oldest structures recognized and are referred to as Phase I folds. They have a low plunge, dominantly to the north, and mainly west-dipping curved axial planes.

More open folds, called Phase II, are also found in each fault slice. They have a low plunge to the north and have axial planes with a low to moderate dip to the west. In general they cause the west-dipping foliation to steepen upward. They have the form in profile of a modified S when viewed from the south. Late folds which in general plunge at moderate angles to the west and northwest and have steeply dipping axial planes striking between west and northwest are found locally. Phase I and Phase II folds are tentatively correlated across the fault slices and with the same sort of structures in the Duncan Lake area 20 miles to the north.

8. The Ainsworth Camp contains more than 50 properties from which silver-lead-zinc has been produced. In addition, there are many other showings from which there has been no production. Total production since the first shipment in 1889 has amounted to 763,858 tons of ore to the end of 1964.

9. The deposits are mainly simple quartz carbonate veins containing shoots and lenses of galena, sphalerite, pyrite, and locally pyrrhotite.

10. The veins form three fairly well-defined systems and two or three clusters, or poorly defined systems. The vein systems are zones of faulting. The Florence trends north 70 to 75 degrees west and dips 45 degrees to the south. The Highland strikes northwest and dips steeply to the southwest, and the Highlander strikes north and dips 45 degrees west parallel to the foliation. The attitudes of the veins and mineralized fractures are summarized in Figure 8 (in pocket).

11. The vein fractures are normal faults with a maximum displacement of a few hundred feet.

12. In veins that transgress the foliation, sulphides tend to be concentrated (*a*) where the veins pass from one rock type to another, (*b*) where the veins branch or split, and (*c*) where the veins have tended to open by displacement during mineralization. Commonly these situations are combined. In the veins parallel to the foliation, the control of mineralized shoots is more difficult to determine.

13. Individual orebodies are small. The largest stoped areas are about 600 feet along the strike, 800 feet parallel to the dip, and 4 to 6 feet wide. Judging from production figures, grades of more than 50 per cent lead and 20 per cent zinc were obtained in ore sorted for direct shipping, whereas grades of about 5 per cent lead and 2 per cent zinc were obtained in ore mined in quantity for milling. The silver content amounts to one-half to one-third of an ounce per ton for every unit of lead.

14. Replacement deposits of galena, sphalerite, pyrite, and pyrrhotite in fractures in the Ainsworth limestone and Early Bird Formation constitute the largest known reserve in the camp. They are geologically like the Bluebell deposits on the eastern shore of Kootenay Lake directly across from the north end of the Ainsworth Camp. On the Lakeshore property in the Ainsworth Camp where this type of deposit has been extensively explored by Cominco Ltd., five groups of fractures along which sulphides have replaced the lower Ainsworth limestone strike between north 65 and 75 degrees west and dip steeply to the south. Replacement mineralization has spread out from the fractures a few inches to a few feet along the foliation at several horizons within the limestone.

15. This study of the Ainsworth-Kaslo area has shown that the fault and fracture system containing the Ainsworth deposits is superimposed on a complexly folded group of rocks. The fracture system itself and its subsequent history controlled the distribution and attitude of the veins and oreshoots.

CHAPTER I.—INTRODUCTION

The Ainsworth-Kaslo area is in the West Kootenay district of southeastern British Columbia on the west side of Kootenay Lake 40 to 60 miles northeast of Nelson. It is an area, referred to throughout this report as the map-area, 25 to 30 miles from north to south and 3 to 5 miles from east to west (*see* Fig. 1). The town of Ainsworth, recently called Ainsworth Hot Springs, is the principal community in the southern part of the area, and the city of Kaslo is in the northern part. Figure 2 is a generalized geological map of the northern part of Kootenay Lake showing the Ainsworth-Kaslo area. Figure 3, in three sections, gives the detailed geology of part of the map-area.

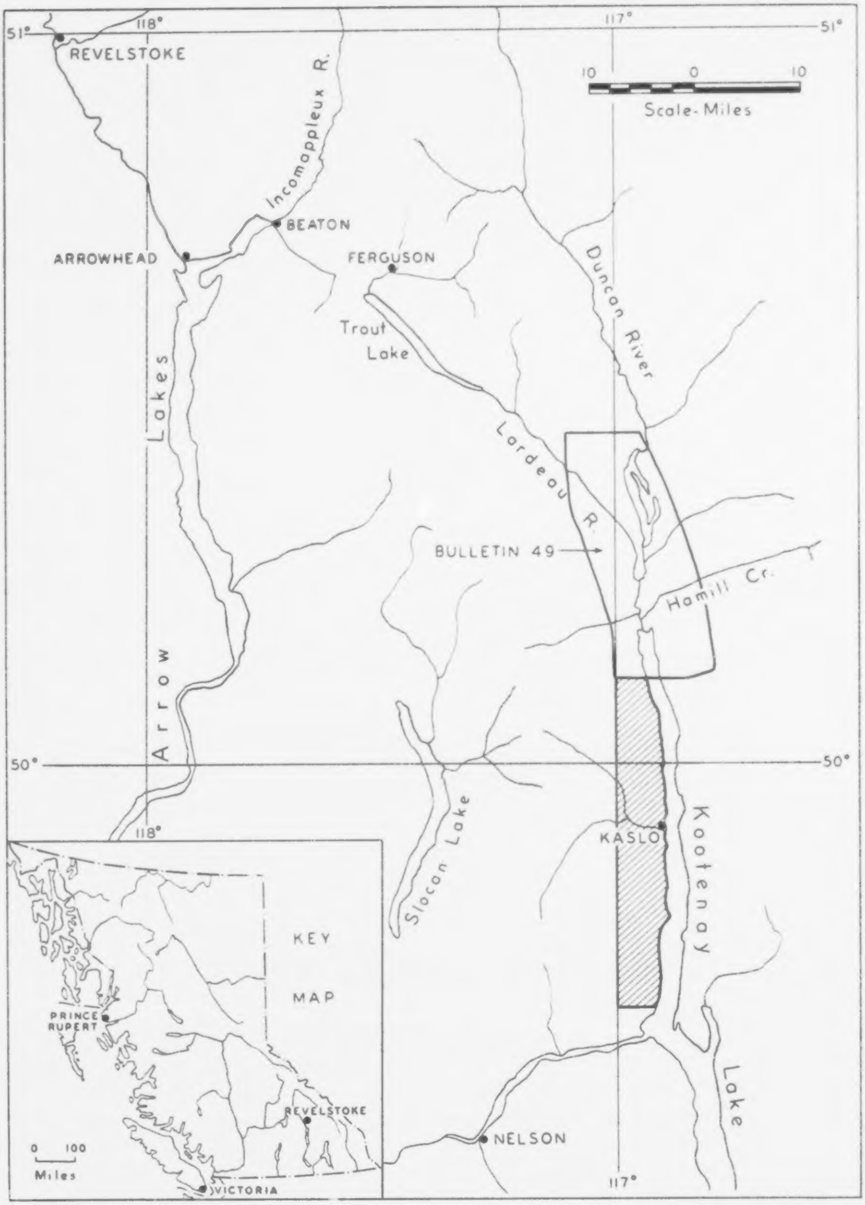
The Ainsworth mining camp is an old one, containing a relatively large number of small mines and prospects from which moderate amounts of silver, lead, zinc, and copper have been produced. The mines and prospects are mainly confined to an area about 8 miles from north to south and less than 3 miles from east to west. The camp is west of Kootenay Lake and east of the Nelson batholith, a major granitic mass containing some mining properties which in this report are not regarded as part of the Ainsworth camp. Essentially all the mines and prospects are in the southern part of the map-area, though a few showings are known near Kaslo. The major mine in the district is the Bluebell of Cominco Ltd. (formerly The Consolidated Mining and Smelting Company of Canada, Limited) on the east side of Kootenay Lake directly across from the north end of the Ainsworth camp. The Bluebell and showings nearby, though separated from the Ainsworth camp by the lake, are geologically part of the camp itself. An area extending north of the camp has been studied geologically in conjunction with the camp because it contains the same geological formations and structures and is an area of better exposure of rock and higher topographic relief.

The Ainsworth-Kaslo area is within the Kootenay arc, a structural belt of regional extent containing highly deformed Palæozoic and Mesozoic rocks (*see* Fyles, 1964, p. 10). All along Kootenay Lake the rocks are of sedimentary and volcanic origin and are mainly in a moderate to high grade of regional metamorphism. They are tightly folded and strongly sheared. In general they strike to the north and dip to the west. The mineral deposits of the Ainsworth camp are veins and mineralized fractures containing galena, sphalerite, pyrite, and locally pyrrhotite commonly associated with quartz and carbonates. Of particular economic interest are mineralized fractures in limestone with zones of replacement adjacent to them. These replacement deposits, which are found in the northern part of the camp, are mined extensively at the Bluebell.

The purpose of this study has been to prepare a factual geological map of the Ainsworth camp on a scale large enough to be used in exploration and to determine the geological structure and its bearing on the mineralization. Though the emphasis is on the general structural setting of the camp, many details of the mineral deposits and many facets of the regional geology of the western shore of Kootenay Lake have come to light and are reported in this bulletin.

TOPOGRAPHY AND ACCESS

Ainsworth is a resort community on the main road from Balfour, on the southern transprovincial highway, to the city of Kaslo on the west side of Kootenay Lake at the mouth of Kaslo River. Balfour is 8 miles south of Ainsworth and


51°
118°
117°
51°
REVELSTOKE
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Scale-Miles
BEATON
ARROWHEAD
FERGUSON
Trout Lake
Duncan River
Lakes
Lardeau R.
BULLETIN 49
Hamill Cr.
Arrow
50°
50°
118°
KASLO
Kootenay
Lake
Slocan Lake
KEY
MAP
PRINCE RUPERT
REVELSTOKE
0
100
Miles
VICTORIA
NELSON
117°

Figure 1. Index map showing location of the Ainsworth-Kaslo area and its relationship to the Duncan Lake area.

Kaslo is 12 miles to the north. In addition to Ainsworth, small communities have grown up from time to time near operating mines, but recently only the Florence townsite, 2 miles north of Ainsworth, has been occupied. Local roads extend from Ainsworth and the Florence townsite to various mines in the camp. Many of these mining-roads were made years ago and are narrow and rough. Logging-roads of the Kootenay Forest Products Ltd., built since 1956, follow some of the mining-roads and have made the valley of Woodbury Creek, and hills north of it, and the northern and higher parts of the Ainsworth camp readily accessible from the mouth of Woodbury Creek and the Florence townsite. The condition of local roads varies from year to year. All roads on which vehicles could drive in 1964 are shown as roads on the map (Fig. 3), and roads in disrepair are shown as trails.

Kootenay Lake occupies part of the Purcell trench, a topographic depression separating the Purcell Mountains on the east from the Selkirk Mountains on the west and extending from the International Boundary northward for almost 200 miles to near the main line of the Canadian Pacific Railway. The hillside west of Kootenay Lake, particularly in the Ainsworth camp, consists of a series of benches between steep rocky scarps that rise in steps from the lake at an elevation of 1,750 feet above sea-level to summits in the Selkirk Mountains of 7,000 to 9,000 feet. The summits are west of the camp, and the highest parts of the camp are at elevations of less than 5,000 feet. Easterly flowing streams have cut relatively deep valleys with steep walls across the slope. The largest streams named from south to north are Coffee, Cedar, Lendrum, Woodbury, Fletcher, Bjerkness Creeks, and the Kaslo River. Krao Creek is a tributary from the north of Coffee Creek, and Lendrum Creek is a tributary of Woodbury Creek, formerly being called its south fork. Most of the mining properties in the Ainsworth camp are between Coffee and Woodbury Creeks.

HISTORY OF MINING

The early growth of mining in the Ainsworth camp is closely linked with the exploration and settlement of the West Kootenay district, which has been described in a number of publications (*see* Cottingham, 1947; Smyth, 1942). Kootenay Lake for many years was a main transportation route. Hot-water springs at Ainsworth attracted early attention and gave the locality the original name of Hot Springs. In 1883 the land around the springs was purchased by George J. Ainsworth, a California millionaire who operated river boats on the Columbia, and the name of Hot Springs was changed to Ainsworth. The first mineral claim in the camp, the Lulu on Woodbury Creek, was Crown granted by Ainsworth in 1884. Most of the claims from which ore has been mined were located and Crown granted between then and 1900. Many of the claims are 600 by 1,500 feet and carry extralateral rights under the apex law which was repealed in 1892. High-grade silver attracted early attention. The first recorded production in the camp was in 1889, when six properties—the Gallagher, Highlander, Krao, No. 1, Silver Hoard, and Skyline—shipped a total of about 300 tons of ore which averaged 100 ounces to the ton in silver. The highest recorded grade in silver was from a shipment of 15 tons from the Skyline, which averaged 225 ounces per ton. The high silver values stimulated early prospecting and development, but they were found to be spotty and scattered, and although small amounts of rich silver ore have been obtained through all the years of production, recent mining has been of lead-zinc ore relatively low in silver.

Production in the Ainsworth camp has come from some 50 properties, and to 1964 had totalled 763,826 tons. Only four properties—the Florence, Highlander, Highland, and No. 1—have each produced more than 40,000 tons of ore, and the remainder have produced 5,000 tons or less.

Before 1930, shipments had been made from most of the producing mines and several, such as the Florence, Highland, Maestro, and No. 1, had had many years of continuous production. Between 1930 and 1935 essentially all the mines in the camp were closed, and continued production did not begin again until 1947. Between 1947 and 1961 most of the mines that had produced in the early years of the camp were reopened.

Prospecting, exploration, and mining have been done by the original owners, by companies, and by local families and individuals who made Ainsworth or Kaslo their home because of the nearby mines. In the period of production before 1930, owners of properties, who most commonly were individuals or partners, began shipments, and in some cases the properties were subsequently bought out or otherwise taken over by companies. In this early period also some of the mines began to be leased to individuals or partners on a royalty or other basis, and much of the production throughout the history of the camp has been by lessees. Among the early owners and lessees the most noteworthy is H. Giegerich, who owned the No. 1 between 1901 and 1910 and in 1913 leased the Skyline. He also held the Maestro and in 1928 he owned the Banker and Spokane. A. D. Wheeler between 1888 and 1917 held and operated several properties, including the Gallagher and the Krao, which he is reported to have sold in 1905 for $100,000. D. F. Strobeck and M. Stevenson did original work on several of the properties before the first war. A. W. McCune, of Salt Lake City, well known in mining throughout the West Kootenay, in 1890 was the grantee for several Crown-granted claims, and in 1916 and 1917 was manager in charge of driving a long exploratory crosscut on the Crow Fledgling ground.

Concentrators were built on several of the properties in this early period of production. In 1893 a mill with a capacity of 50 tons per day was built at the No. 1, and it continued to operate with capacity increased to 500 tons per day until about 1900. Other mills were built at the Skyline and Silver Hoard. In 1901 a concentrator was completed by the Highland Mining Company on a small delta at the mouth of Cedar Creek (*see* Plate XV) and an aerial tram-line constructed from the Highland mine to the mill. About 1912 both the Highland and the No. 1 were operated by Cominco Ltd. A tram-line was built from the No. 1 to the mill at the mouth of Cedar Creek, which was in operation until about 1926. A concentrator near the mouth of Princess Creek was built in 1916 by Florence Silver Mining Company Limited. It had a capacity of 200 tons per day and received ore by an aerial tram from the No. 5 and No. 9 levels. At the Highlander property a concentrator was built in 1897 and operated for many years. Of these early concentrators, only the Florence, considerably modified, is in existence today. The present Highlander (Yale) mill was built in 1950. In 1952 a custom mill with a capacity of 75 tons per day was erected north of the mouth of Woodbury Creek and was dismantled in 1963.

One of the most interesting early mining plants in the camp was a Taylor air compressor on Coffee Creek near the mouth of Krao Creek. This device, working on a principle patented by C. H. Taylor, of Montreal, compressed air by falling water (*see* Peele, 1918, Compressed Air Magazine, Vol. 68, No. 10). The plant, using water from Coffee Creek, carried in a flume along the north canyon wall of the creek, had a capacity of 5,000 cubic feet of free air per minute at 85 pounds per square inch and developed 600 horsepower. The water was dropped vertically down a wood-stave pipe into a vertical shaft about 100 feet deep at the edge of the creek. The air was piped 2 to 3 miles to mines near Ainsworth. The compressor was installed in 1897 and supplied compressed air to mines as far away as the United until about 1910.

Recent production of lead and zinc largely resulted from the rise in the price for these metals in 1947. In 1948 Yale Consolidated Lead and Zinc Mines, reorganized in 1949 as Yale Lead & Zinc Mines Ltd., acquired a large block of claims near Ainsworth. A new mill was built near Kootenay Lake below the Highlander mine in 1950, which operated more or less continuously until 1961. Most of the ore for the mill came from the Highlander mine, but small shipments were made from other properties held by Yale or shipped on a custom basis. Over a period of years a large block of claims in the northern part of the camp was acquired by Western Mines Limited. In 1951 this company bought the Kootenay Florence mine and mill from Ainsmore Consolidated Mines Limited, who had obtained it from the Wartime Metals Corporation. From 1947 to 1960 most of the properties in the camp made shipments either directly to Trail or to the Yale or Florence mills. Ore on mine dumps or in places that had been known for many years was taken out by owners or lessees. By 1960 most of the known ore had been shipped, and relatively little exploration beyond the known oreshoots had been done. One notable exception was the work of Cominco Ltd. between Cedar and Woodbury Creeks. Beginning about 1952, geological studies were made of this area, and the close similarity between showings on the Lakeshore property of Western Mines Limited and the Bluebell orebodies was noted. An extensive drilling programme in search of replacement ore of the Bluebell type was carried out in 1955 and 1956, and some underground work was done in 1957. The first results of the drilling were encouraging, but later drilling and underground work showed that replacement was less extensive than expected. Only a limited amount of mining by lessees has been done. The ore blocked out by this drilling constitutes the largest known reserve in the camp.

In this later period of mining, as in the early one, the development and successful operation of the mines has depended on the skill and ingenuity of local people either by themselves or in co-operation with company managers and engineers. At present, prospecting, exploration, and some mining are being done intermittently by individuals and small companies. Aside from external economic factors, the future of mining in the camp depends on the success of this relatively limited exploration.

GEOLOGICAL WORK

Several detailed and regional geological studies have been made both in the Ainsworth camp and along Kootenay Lake. References to all the published work on the area are included in the bibliography (*see* p. 14). The studies of most significance are those of S. J. Schofield (1920), H. M. A. Rice (1944), and G. E. P. Eastwood (1951, 1952) in the Ainsworth camp itself, and of H. M. A. Rice (1941), C. E. Cairnes (1934), and P. Crosby (1960) of the Kootenay Lake region in general.

The idea of making another geological map of the Ainsworth camp was the outcome of a reconnaissance in the area made by C. G. Hewlett and the writer in 1956. In this reconnaissance it was clear that the existing reports did not adequately describe the structure and that even the most detailed maps of the area did not portray the geology in a useful and factual manner. The present study, which was begun in 1960, aimed firstly at making a factual geological map of an area, including all the mines of the camp, on a scale large enough to be of use in exploration, and secondly at determining the structure of the camp by studies of the geology beyond the camp itself, mainly to the north. The work occupied parts of the field season of 1960, 1961, and 1964, and all of the season of 1963, and was carried on in conjunction with studies in the Duncan Lake area some 30 miles to the north (*see* Fyles, 1964). The field work on this project has taken a total of 10 months and laboratory work has been done during parts of three winter seasons.

A special base map for this project was prepared on a scale of 500 feet to the inch from low-level air photographs by the British Columbia Department of Lands, Forests, and Water Resources. Plotting of geology on this base was mainly by air photos supplemented by compass and pace traverses and some plane-table surveys. Studies and maps of properties were made with the aid of plane-table and compass and tape surveys as well as mine plans obtained from the owners and from company and Government files. Many useful records and maps were lost when the office at Yale Lead & Zinc Mines Ltd. was destroyed by fire in December, 1960. All of the Ainsworth camp has been mapped except the parts studied by Eastwood, for which his maps were used. Plane-table maps of Cominco Ltd., which cover large areas between Cedar and Lendrum Creeks, were used as guides in the field but have been replotted. Crown-granted claims shown on Figure 3 were compiled in 1964 from legal surveys, maps of Cominco, and from the locations of corner posts found and plotted in the field.

ACKNOWLEDGMENTS

Able assistance was given in the field by P. M. Clifford, D. J. Templeman-Kluit, and D. F. Rebagliatti in 1960; by A. J. Sinclair, Templeman-Kluit, and A. Armour-Brown in 1961, and by Armour-Brown in 1963. The writer is indebted to J. Richardson and Frank Shannon, of Cominco Ltd., and to H. M. Turner, of Western Mines Limited, for permitting the use of company maps and reports and for discussing freely the geology of the mines and of the district. During the field work many courtesies were extended to the writer and his party by the people of Ainsworth. The friendly help of Tom Hawes, Tom Lane, and D. H. Norcross in pointing out both old and new features of many of the properties was of great value in the study.

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CHAPTER II.—GENERAL GEOLOGY

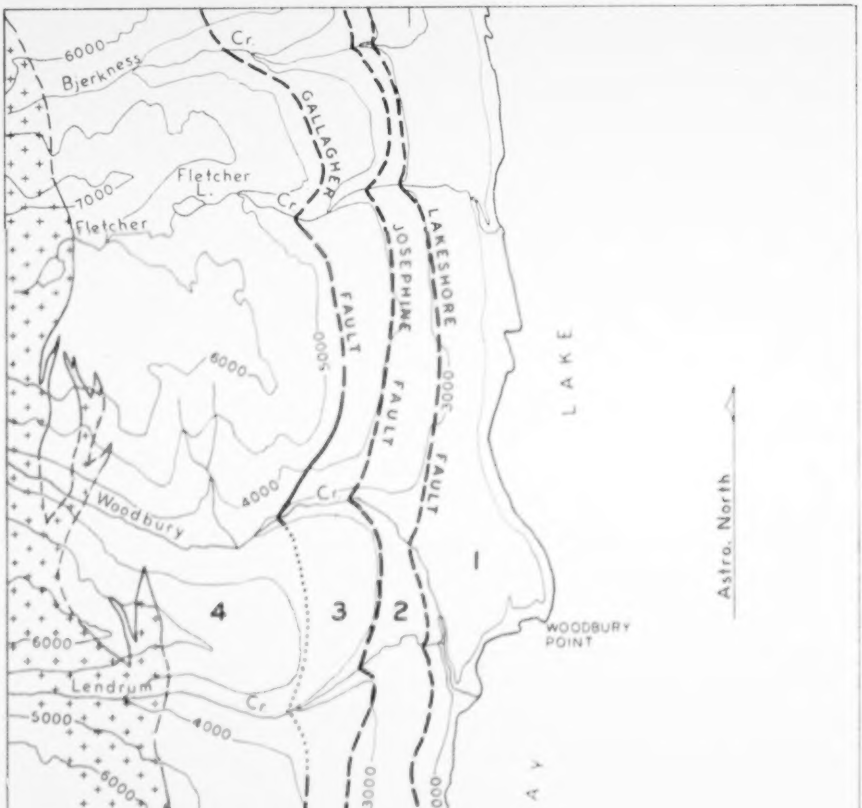
The Ainsworth-Kaslo area contains a complexly deformed group of sedimentary and volcanic rocks in various grades of regional metamorphism. They comprise part of the Kootenay arc, a major structural belt extending from Revelstoke to beyond the International Boundary (*see* Fyles, 1962; 1964, p. 10). Within the Ainsworth-Kaslo area the sedimentary and volcanic rocks are truncated on the west by the Nelson batholith, a granitic mass extending many miles to the west. They are intruded by lenticular granitic sills and by mafic dykes and sills.

Because of complexities of the structure and vagaries of the metamorphism, it has not been possible to establish a stratigraphic succession within the area. Previous workers have named formations and determined their distribution and relative age (*see* Schofield, 1920; Rice, 1944) on the assumption that the lithologic succession as exposed, which strikes north and dips to the west, is right side up and on the eastern limb of a major syncline (Schofield, 1920, p. 26). Detailed studies in this area and beyond it have shown formations to be repeated many times by folding and faulting, and that many of the lithological units, because of the structure, are discontinuous. In the strictest sense there is no stratigraphy along the west side of Kootenay Lake, merely a succession of lenticular rock units that are the deformed remnants of what once was a more or less continuous stratigraphic succession. Parts of the succession can be recognized locally, though very few rocks display primary structures from which the stratigraphic top may be determined. Some of these parts can be integrated within the area and tentatively correlated with formations beyond the area.

Considerable interpretation has gone into the development of the geological picture presented in the following pages. In order to give the factual material as free as possible from interpretation, the map and sections (Figs. 3 and 4) and the descriptions in this chapter show the rock types and structures as they appear on the ground. This has led to a complicated map legend and to an unconventional descriptive treatment in which the lithology and structure of four fault slices are described together. Tentative correlations, which in their presentation may seem more certain than they really are, are given in the table of formations and are summarized on the map, Figure 2.

SUMMARY

The Ainsworth-Kaslo area contains rocks which near Kootenay Lake dip at moderate angles to the west and are split by strike faults essentially parallel to the regional foliation. South of Kaslo three of these faults, thought to be more significant than the others, have been named, from east to west, the Lakeshore, Josephine, and Gallagher faults. They divide the area into four elongate slices trending north and dipping to the west (*see* Fig. 5). The first slice along the shore of Kootenay Lake is 2 to 3 miles wide near Kaslo and to the south passes beneath the lake. It contains rocks of the Lardeau Group, which are in the highest grade of regional metamorphism. The next slice to the west, or the second slice, is about a mile wide south of Ainsworth and thins northward to a few hundred feet wide near Kaslo. It contains rocks of the Milford and Kaslo Groups and is bounded on the west by the Josephine fault. The third slice, between the Josephine and Gallagher faults, is more than a mile wide in the north and thins somewhat to the south. It contains rocks thought to belong to the Milford, Kaslo, and Slocan Groups. The fourth slice lies between the Gallagher fault and the Nelson batholith and has many


Cr.
6000
Bjerkness
GALLAGHER
Fletcher L.
7000
Fletcher
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JOSEPHINE
LAKESHORE
FAULT
FAULT
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FAULT
6000
5000
3000
LAKE
Astro. North
4000
Woodbury
Cr.
1
4
3
2
WOODBURY POINT
6000
Lendrum
Cr.
5000
4000
6000
3000
2000
KOOTENAY
Cedar
Cr.
49°45'
AINSWORTH
Krao
Cr.
MILE POINT
6000
5000
4000
Coffee
Cr.
3000
3000
116°55'
1 First slice
2 Second slice
3 Third slice
4 Fourth slice
Nelson Batholith
1 0 1 2
SCALE-MILES

Figure 5. Map showing the major strike faults and the fault slices in the Ainsworth camp.

northerly trending faults within it. In contrast to those in the three slices to the east, the rocks in it are folded in such a way that westerly dipping formations steepen upward and locally are vertical or dip east. Rocks in the fourth slice probably belong to the Slocan, Kaslo, and Milford Groups and are in the lowest grade of regional metamorphism. A zone of deformation and thermal metamorphism related to the Nelson batholith extends as much as half a mile eastward from the exposed contact of the batholith. The intrusive deformation and thermal metamorphism are superimposed on the regional deformation and metamorphism.

Rocks of the first fault slice consist of fine- to medium-grained mica schists commonly containing porphyroblasts of brown garnet and lenses of grey marble. They are divided into a non-calcareous part, the Princess Formation, which lies immediately east of the Lakeshore fault and a calcareous part, called the Early Bird Formation, lying east of the Princess. The Princess Formation, consisting of mica schist, quartz-mica schist, and garnet-mica schist, has an apparent thickness of 500 to 1,000 feet and has been traced from Ainsworth to the Kaslo River. North of the Kaslo River the Early Bird Formation and the Princess Formation cannot be readily distinguished. The highest metamorphic grade is in the Early Bird Formation on Woodbury Point, where locally kyanite and sillimanite are present. The grade decreases to the west and to the north. A few miles north of Kaslo, in the biotite and muscovite grades, the Princess and Early Bird Formations pass northward along strike into calcareous and non-calcareous grey mica schist of the Index Formation in the lower part of the Lardeau Group, which occurs widely in the Duncan Lake area.

The second fault slice contains mainly fine-grained grey mica schists and micaceous quartzites interlayered with dark-grey limestones and marbles and with hornblende schists and gneisses. The hornblende schists and gneisses are mainly sills belonging to the Kaslo Group, and the other rocks are part of the Milford Group. Within the Milford the stratigraphic succession is not known, but it is clear that some of the formations are repeated several times by folding or faulting, and that the same formations occur at different places in different grades of metamorphism. In the Ainsworth camp thin but fairly continuous layers of limestone are medium to coarsely crystalline and banded in shades of grey or white. They are interlayered with grey fine-grained mica schists and micaceous quartzites. The limestones are known by local names as the upper and lower Ainsworth, Libby, Krao, Dictator, and Banker limestones.

The third fault slice contains mainly grey knotted mica schist and very fine- to medium-grained limestones. In the northern part, grey slate, argillite, and cherty rocks are interlayered with the limestone and with sill-like masses of greenstone. The sedimentary rocks in the northern part of the third slice belong to the Milford Group and the greenstones belong to the Kaslo Group.

The fourth fault slice contains rocks in a low grade of regional metamorphism intruded and thermally metamorphosed on the west by granitic rocks of the Nelson batholith. The rocks include limestone, dolomite, dark-grey and brownish argillite, and green volcanic rocks of various types. Most of the sedimentary rocks are in the Slocan Group, but some are probably in the Milford, and the volcanic rocks at least in part can be correlated with the Kaslo Group. All these rocks are complexly folded and faulted.

Sills and lenses of fine-grained gneissic granite and granodiorite intrude the metamorphic rocks of the area. Locally near Kaslo and north of Kaslo there are irregular masses of pegmatite. The granitic rocks along the western edge of the area are part of the Nelson batholith and are largely porphyritic and non-porphyritic quartz monzonite and granodiorite. Lamprophyre sills and dykes intrude all the rocks in the map-area.

STRIKE FAULTS

The Ainsworth-Kaslo area is divided into four panels or slices (*see* p. 17) by three northerly trending strike faults. These slices form the basis of the following descriptions of the lithology and structure, and consequently the faults are described first. Three faults thought to have the largest displacement and to continue as regional structures beyond the map-area are named the Lakeshore, Josephine, and Gallagher faults from exposures near these mines. Other strike faults are present, particularly in the fourth fault slice. Also, small cross-faults are present, which are especially significant and well known in the Ainsworth camp where they are mineralized. Only the strike faults are considered here as they control the regional distribution of the formations. The mineralized cross-faults are described in Chapter III.

The strike faults are difficult to find in the field and have not been described by previous workers. Their discovery depends on detailed work covering a relatively long distance along strike. Even though good local evidence for faulting may be found, considerable interpretation is required in recognizing the presence of the major strike faults and in plotting them on the map. Evidence for the faults and interpretation of their significance is presented in the following paragraphs.

The *Lakeshore fault* forms the boundary between the first and second fault slices. It has been followed from near Ainsworth, south of which it is beneath Kootenay Lake, to near Kaslo River and probably continues beyond the map-area at least as far north as Schroeder Creek. The fault zone is known to be exposed at three places within the map-area—on Cedar Creek, in the Lakeshore and Kootenay Florence adits, and on Woodbury Creek. At each of these places it is at or near the western contact of the Princess Formation (*see* p. 21) and it appears to follow this contact throughout its length. On the north side of Cedar Creek about 800 feet west from the highway, the fault is marked by 50 to 100 feet of dark-grey highly sheared rock lying between the Princess Formation and hornblende gneisses to the west. A narrower zone of very schistose rock is exposed at this contact near the portal of the Lakeshore No. 2 adit about a mile to the north of Cedar Creek. On the north side of Woodbury Creek the western contact of the Princess Formation is not abnormally sheared, but many small strike faults marked by sheared and crushed zones lie to the west, and less than 500 feet to the west is a spectacular fault zone known locally as the Woodbury " soft lead." It is a zone 100 to 200 feet wide of sheared and crushed dark-grey carbonaceous rock containing scattered pyrite.[*]

These exposures of the Lakeshore fault on the hangingwall of the Princess Formation may or may not be taken as evidence of a regional strike fault. Regional correlations, however, show that part of the stratigraphic succession is missing along this fault, and that when traced far enough to the north the fault transgresses the formations. The Princess is correlated with the lower part of the Lardeau Group (*see* p. 22), which, 5 miles north of Kaslo on the eastern slopes of Milford Peak, is in fault contact with the upper Lardeau Group, which, in turn, is in fault contact on the west with rocks of the Milford Group. South of this locality the upper Lardeau is cut out by the convergence of the two faults, and farther south, in the Ainsworth-Kaslo area, the lower Lardeau (Princess Formation) is separated from the Milford Group (*see* Fig. 2) by the Lakeshore fault.

The *Josephine fault* forms the western boundary of the second fault slice. It is well exposed in workings on the Josephine claim in the Highland mine area north of Cedar Creek. It has been traced throughout the map-area and extends beyond it. South of Fletcher Creek the fault separates a thick layer of hornblende schist on the east from a thicker layer of grey knotted schist on the west. Just south of Fletcher Creek the hornblende schist is cut out by the fault, and north of Fletcher Creek hornblende and chlorite schists, phyllites, and limestones come in on the western side. The fault gradually transects formations along strike, and in so doing toward the north cuts down through the second fault slice; north of Kaslo River it probably joins the Lakeshore fault (*see* Fig. 2).

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[*] Samples across the zone assayed less than 0.1 per cent in copper, lead, and zinc. Three tons of sorted ore shipped from the soft lead in 1964 yielded: Silver, 31 ounces; lead, 1,540 pounds; zinc, 146 pounds. *See* Sharon, Table I.

The fault dips to the west at moderate angles, probably more steeply than the layers. It is marked by a narrow zone of sheared and crushed rock with a wider zone of complexly folded and somewhat altered rock on the footwall side. The sheared and crushed zone is exposed at a number of places and is followed by quartz veins in the Josephine part of the Highland mine. Hornblende schists adjacent to the fault are complexly folded on axes with steep but irregular plunges. These folds are not found more than a few hundred feet from the fault. The schists in this zone are abnormally rich in pyrrhotite, which causes rusty weathering.

The *Gallagher fault*, named from the Gallagher property south of Lendrum Creek, has been mapped only in the northern part of the area. It separates the third fault slice from the fourth, cutting across a number of formations and structures in each. The best exposures of the fault are on the north slope of Woodbury Creek, where the fault is west of and parallel to a layer of tightly folded limestone and transects limestones, grey argillites, and volcanic rocks which lie above the fault and terminate abruptly against it (*see* Fig. 4, section D-D′). The fault cannot be located with certainty south of Woodbury Creek, but it probably passes through a thick mass of limestone between Woodbury and Lendrum Creeks and follows the eastern contact of another thick limestone lens south of the creek through the Gallagher property, near which it is marked by a zone of brecciated limestone and sheared grey mica schist. Rocks farther south, near the fault, are poorly exposed, but the fault probably passes east of the No. 1 mine and follows the eastern contact of a limestone lens exposed south of that mine (*see* Fig. 3). It is possible that the Gallagher fault continues southward along the eastern contact of the Nelson batholith near Coffee Creek (*see* p. 40).

No direct evidence has been found for the magnitude of nor the direction of displacement on any of these faults. Scattered observations suggest that the faults dip to the west more steeply than the formations and that the Lakeshore fault probably has a lower dip than the others. Rocks in the fault slices become progressively younger toward the west, and the simplest explanation for this is that the dip-slip movement on the faults has been down on the west. Even this conclusion, however, is impossible to prove because the rocks within the blocks are complexly folded.

FIRST FAULT SLICE

Lithology

Rocks of the first fault slice comprise an assortment of rusty-weathering mica schists of medium to high metamorphic grade. Garnet-quartz and lime-bearing mica schists are the most common, but kyanite- and sillimanite-bearing schists are found locally on Woodbury Point. Three formations within the fault slice were distinguished by Schofield, but only two, the Princess and the Early Bird, are distinctive enough to be mapped. These formations are exposed in cliffs and road cuts along the shore of Kootenay Lake from Ainsworth to a mile or so north of Kaslo. The Princess can be distinguished readily from the Early Bird south of Kaslo River, but not to the north where the two intergrade and become indistinguishable. These formations have a fairly good schistosity which dips at low to moderate angles to the west and is parallel to the rock layers within the formations.

Rocks of the first fault slice are in a medium to high grade of regional metamorphism. Kyanite seen in the field on Woodbury Point and in the bay north of it and sillimanite discovered in thin-sections (*see* Crosby, 1957) are taken to indicate the area of highest metamorphic grade, even though the discovery of these minerals depends somewhat on good rock exposures and their development is controlled in part by the composition of the rocks. Kyanite is not found away from the shore, and most of the rocks in the first fault slice are in a medium grade of regional metamorphism corresponding to the classic garnet and staurolite zones.

Early Bird Formation

The Early Bird Formation, originally named by Schofield (1920, p. 10), is here redefined to include also the Point Woodbury Formation which Schofield mapped on Woodbury Point. The two formations are lithologically very similar and cannot be readily separated even at the type locality.

The Early Bird Formation is fine- to medium-grained calcareous mica schist ranging widely in carbonate content. Outcrops are rusty and characteristically have a rough surface where calcareous parts have weathered more deeply than the non-calcareous. The best exposures are along the road cuts for a mile or so north and south of Woodbury Creek, and along the shore of Kootenay Lake. Much of the formation consists of thin layers, knots, and lenses of calcareous mica schist and gneiss in medium-grained crystalline limestone. Mica schists with only small scattered calcareous lenses comprise another large part of the formation. Lenses of medium-grained grey crystalline limestone relatively free of silicates are present locally. Some are as much as 50 feet thick and continue a few thousand feet along strike. They grade laterally and along strike into calcareous schists. Fairly blocky mica schists and garnet-mica schists and gneisses are common on Woodbury Point and along the strike for a few miles north of the point. They contain large lenses of crystalline limestone and in some layers porphyroblasts of sillimanite and kyanite. Thin layers of medium-grained calcareous amphibolite are present near Mirror Lake. Rarely, especially associated with shear zones parallel to the foliation, the schists are dark grey to black and highly carbonaceous.

In two dozen representative specimens studied under the microscope, quartz, calcite, muscovite, and biotite are the principal minerals. Minor amounts of tourmaline, apatite, sphene, and pyrrhotite are present in most thin-sections. Red garnets, kyanite, and sillimanite occur locally. Plagioclase, which amounts to as much as 30 per cent of some rocks, is andesine or labradorite.

Princess Formation

The Princess Formation lies west of and spatially above the Early Bird. It consists of garnet-quartz-mica schist and forms a distinctive rock unit 500 to 1,000 feet thick extending for 15 miles from Mile Point to the slope north of Kaslo River. North of Kaslo River, where the metamorphic grade decreases and where large parts of the Early Bird Formation are non-calcareous, it is indistinguishable from the Early Bird. The Princess Formation, which weathers a yellowish brown, forms cliffs and open moss-covered outcrops throughout its length. Glistening foliation surfaces studded with medium-grained red garnets are found in much of the formation and make it distinct from finer-grained grey mica schists to the west. The Princess is uniform in lithology through most of its length but varies somewhat in quartz and garnet content across the strike. Calcareous lenses are found only near the footwall* of the formation, where it grades into the Early Bird.

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* The terms "footwall" and "hangingwall" are used in this report to refer respectively to the lower and upper sides of the formations in their present positions. The terms have no stratigraphic connotation. Inasmuch as most of the formations dip to the west, the footwall is usually the eastern and the hangingwall the western side.

In mapping, the footwall has been placed at the first prominent layer of crystalline silicate limestone in the Early Bird, but small lenses of calcareous rock commonly containing dark-grey amphiboles occur as much as 100 feet west of the first prominent limestone and are in the Princess Formation. There is no certainty that the footwall as mapped is a stratigraphic horizon; it is more probably a complexly interfolded zone of lime-schist layers rendered lenticular by deformation.

The hangingwall of the Princess Formation is marked by a zone 20 to 50 feet thick of lustrous grey mica schist considered to be the sheared rock in the Lakeshore fault zone (*see* p. 19). Dark-green calcareous hornblende gneiss is west of the Princess Formation in the Ainsworth camp and locally also to the north. Where the hornblende gneiss is not present, grey and white crystalline limestone lies west of the Princess Formation.

In thin-sections of typical specimens of the Princess Formation, quartz, muscovite, biotite, and labradorite are the main constituents and tourmaline and apatite are common minor constituents. Some microscopic layers are crowded with apatite. Clear subhedral garnets and rare staurolites form porphyroblasts. Muscovite is somewhat altered to chlorite and plagioclase to sericite, but in general the rocks appear fresh in contrast with knotted schists of the third fault slice in which the porphyroblasts are highly altered (*see* p. 30).

CORRELATION

Rocks of the first fault slice belong to the lower part of the Lardeau Group. This group is named from the Lardeau district beyond the north end of Kootenay Lake, where it outcrops widely and is made up of a thick succession of phyllite and argillite, quartzite, grit, basic volcanic rocks, and minor limestone. The Badshot limestone near the base of the group, one of the most significant marker formations in the Kootenay arc, is exposed along the west shore of Kootenay Lake between 1 and 2 miles north of Kaslo, where it is infolded with quartzites of the Hamill Group (*see* Fig. 2). The Badshot is a grey and white medium- to coarse-grained marble forming two layers, one of which follows the shore of the lake and the other lies above a high bluff of quartzite near the road. The quartzite is brown and micaceous with a few white layers. These marbles and quartzites lie east of the Early Bird Formation, which, traced northward into regions of lower metamorphic grade near Milford Creek, becomes a grey limy mica schist characteristic of the lower part of the Index Formation and is continuous with the Index Formation of the Duncan Lake area.

It is clear from the above relationships that the Early Bird and Princess Formations are to be correlated with the Lower Index Formation of the Lardeau Group. The Early Bird is a calcareous part and the Princess a more siliceous non-calcareous part of the Lower Index.

No fossils have been found in rocks of the first fault slice. The Badshot limestone is generally taken to be Lower Cambrian from fossils found in the Salmo area 50 miles to the south and in the Rogers Pass area 100 miles to the north (*see* Fyles, 1964, p. 35). The Early Bird and Princess Formations may reasonably be thought of as Early Palæozoic.

STRUCTURE

Rocks of the first fault slice have a more or less well-developed foliation that dips at low to moderate angles to the west. In micaceous rocks the foliation is schistosity, and in calcareous and gneissic rocks it is a layering in which individual layers range from a fraction of an inch to a few inches thick. The schistosity of micaceous rocks is parallel to the formational contacts. Stereographic plots of the foliation show an average dip between 30 and 40 degrees to the west and a range in the strike from 15 degrees east of north to 10 degrees west of north. The wide range in strike results from open west-plunging folds which are outlined by a broad curvature of the formations. Very few small folds are to be seen in the first fault slice. On Mile Point and near the old ferry dock at Ainsworth the Princess Formation contains complex minor folds which plunge northwest at about 15 degrees. They are asymmetric and overturned with axial planes dipping to the southwest. Elsewhere boudinage, with axes plunging either down the dip of the foliation or gently to the north, causes local warps of the foliation (*see* Plate X).

Lineation is present in most outcrops in the first fault slice. It consists of trains of mica flakes, elongate clusters of garnets, or oriented crystals of tourmaline. Locally fine crinkles of schistosity and quartz-feldspar rods produce lineations. Most of the lineations have a low plunge either to the north or to the south. Generally two gently plunging lineations intersecting at a small angle are present. The relative age of the two lineations is uncertain, and fold hinges parallel to them have not been found. The minor folds at Mile Point and near the Ainsworth dock appear to be later than the lineations and not related to them. The regional structure indicates that the rocks of the first fault slice have been intensely deformed, and it is probable that the lineations are related to folds, the hinges of which are obscured by later folding.

North of Kaslo the pattern of folding in the first fault slice has been determined from mapping of the Hamill, Badshot, and Lower Index Formations in Schroeder Creek and correlating the structure there with that of the Duncan Lake area. Figure 6 shows a diagrammatic cross-section in the lower part of Schroeder Creek. Although it has not been possible without mapping the east side of Kootenay Lake to be certain of the structural position of the rocks in the lower part of Schroeder Creek, it is clear that they have undergone two phases of folding and that the structures have the same pattern as those in the southwestern part of the Duncan Lake

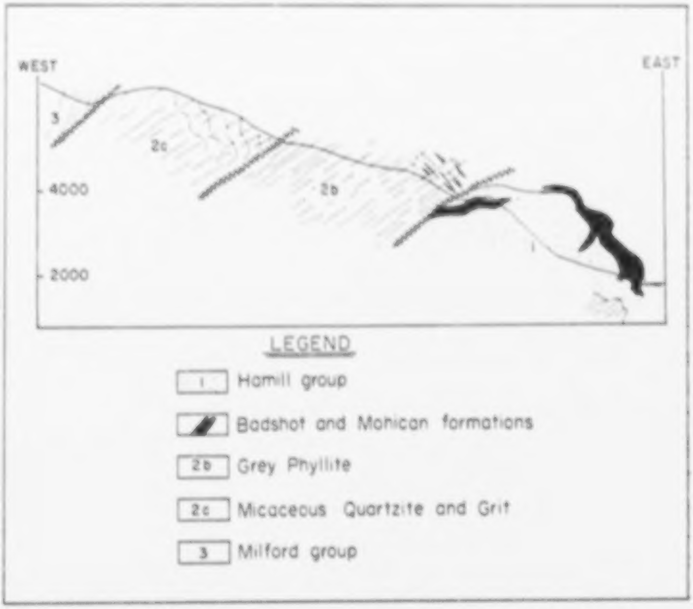


Figure 6. Diagrammatic structural section near Schroeder Creek.

area (*see* Fyles, 1964). Folds of both phases have essentially parallel axes plunging at low angles to the north. The first folds are isoclinal and cause complex repetitions of the Badshot Formation and the upper part of the Hamill Group. These folds cannot be mapped in the Index Formation, which contains no marker beds, but some are seen in it as minor folds. The second folds are fairly open, with axial planes dipping at low to moderate angles to the west parallel to a more or less well-developed cleavage, which in the Index Formation locally becomes the dominant foliation. From this it is concluded that south of Schroeder Creek in the Princess and Early Bird Formations at least part of the schistosity, which dips at low to moderate angles to the west, is related to the second phase of deformation. It is also concluded that the most prominent lineation is parallel to the axes of second phase folds which are obscure in the rocks south of Kaslo.

SECOND FAULT SLICE

The second fault slice is bounded on the east by the Lakeshore fault and on the west by the Josephine fault (*see* p. 19 and Fig. 5). South of Ainsworth it is more than a mile thick and thins gradually northward to less than 1,000 feet near Kaslo. It has not been mapped north of the eastern slope of Mount Buchanan. The northward thinning of the slice is caused mainly by the Josephine or hanging-wall fault gradually transecting the formations, and it is probable that the slice ends north of Mount Buchanan where the Josephine and Lakeshore faults join.

LITHOLOGY

Rocks of the second fault slice are fine-grained limy and non-limy grey mica schists, micaceous quartzites, crystalline limestones, and fine-grained hornblende schists. They belong to the Ainsworth and part of the Josephine Formations described by Schofield (1920, p. 10), who distinguished also the Krao, Libby, and Dictator limestone members of the Josephine Formation. The names of the limestones are shown on the map (Fig. 3), and the names given by Schofield are retained. The term " Josephine Formation," however, is not used because it originally included heterogeneous rock units which now are subdivided into a number of distinctive formations.

Limestones

The limestones of the second fault slice are very similar in gross aspect. They resemble also limestones in the first slice but differ from those to the west in the third and fourth fault slices (*see* pp. 30 and 33), which are finer grained and fetid. In the second fault slice the limestones weather blue-grey and range in colour from light grey to bluish black. Most commonly dark- or light-grey carbonaceous layers alternate with light-grey, almost white layers an inch or so thick. Thin micaceous partings, lenses of rusty-grey mica schist, and dark-grey to black siliceous layers are widespread but minor in amount and are more prominent in some limestones than in others. Detailed mapping has shown that some of the limestones are structural repetitions of others, and it is possible that there are not more than two stratigraphically distinct limestones in the second fault slice.

The *lower Ainsworth limestone* outcrops from the Lakeshore mine near Princess Creek southward through Ainsworth and along the shore of Kootenay Lake to the north side of Queens Bay south of the map-area. In these exposures it is 350 to 400 feet thick. North of Princess Creek the limestone is exposed in the banks of Lendrum and Woodbury Creeks and intermittently northward to beyond Kaslo River. In these exposures it is less than 100 feet thick and is probably lenticular.

The *upper Ainsworth limestone,* which is lithologically very similar to the lower Ainsworth limestone, is a lenticular mass lying 500 to 1,000 feet west of the lower limestone in the area between Ainsworth and the Kootenay Florence mine. On No. 9 level of the mine it is a grey banded crystalline limestone, lighter in colour and coarser in grain near the hangingwall than toward the footwall. It has a thickness of about 200 feet on this level and thins upward. The limestone is not exposed on surface above the mine or to the north, but it is exposed near Cedar Creek, where it is also about 200 feet thick and thins rapidly to the south near Munn Creek. South of the latter creek, only a series of lenses of limestone up to 50 feet thick and a few hundred feet long, which may be equivalent to the upper Ainsworth limestone, are present in schists west of the lower limestone.

The *Libby* member (*see* Schofield, 1920, p. 13) has been traced northward from the north side of Cedar Creek near workings on the Libby claim, through the Highland mine area, where it outcrops at the portal of No. 3 level, to the trail from the Highland to the Gallagher camps. It is a light-grey to white crystalline dolomite containing needles of tremolite and veinlets of green amphibole and quartz. The Libby is not known away from this area north of Cedar Creek, but calcareous argillites and quartzites which are west of the dolomite in the Highland mine continue on strike both to the north and to the south.

The *Dictator and Krao limestones* are found only in the southern part of the Ainsworth camp and extend south beyond the map-area. They have a complex outcrop pattern and are probably the same stratigraphic unit (*see* Fig. 3 and p. 28). These limestones weather blue-grey and are banded grey to dark grey on fresh surfaces. Locally they are highly quartzose and carbonaceous. They contain lenses of grey and white quartz and grade at the margins into thin-bedded dark-grey and white limy cherts and platy quartzites. Near Coffee Creek they are interfolded with blocky buff calcareous quartzites which become more abundant toward the south.

Schists and Quarzites

The calcareous and non-calcareous schists and quartzites in the second fault slice are difficult to subdivide and to map. The two dominant rock types are fine-grained grey mica schists and various sorts of quartzites. Quartzites predominate toward the hangingwall of the group and in the southern part of the Ainsworth camp south of Loon Lake. They are commonly interlayered with hornblende schists which are sill-like intrusions and disrupt the continuity of the lithologic succession. The quartzites include dark-grey and white thinly banded cherty rocks, brownish micaceous quartzites with a poor foliation, buff to brown massive quartzites, and locally white quartzites. All of these quartzites, particularly the brown massive and the cherty ones, are commonly calcareous, and the lime weathers out leaving a rough porous weathered surface. Somewhat calcareous micaceous and cherty quartzites interlayered with hornblende schists are common in the Highland mine area. Much the same sort of quartzite is found near the Spokane, Maestro, Banker, and Highlander vein systems. Cherty quartzites are present along the margins of the Krao and Dictator limestones. Blocky brown limy quartzites occur near the Eden and Crescent mine and south of it, and are the dominant type of quartzite between Coffee Creek and Queens Bay.

The grey fine-grained mica schists, which include rocks described by Eastwood (1951, p. 146) as greywackes, phyllites, and silver schists, are associated with the Ainsworth limestones on the footwall side of the group. These schists are commonly calcareous and locally contain lenses of limestone and of hornblende schist. In all these rocks small porphyroblasts of garnet are widely scattered, and locally needles of hornblende are present.

Thin-sections of the fine-grained mica schists contain mainly quartz, feldspar, biotite, and muscovite with minor amounts of apatite, tourmaline, and sphene. Calcite and carbonaceous material are present in varying amounts. Small porphyroblasts of garnet are common, and needles of hornblende and colourless tremolite occur in some of the calcareous mica schists. The quartzitic rocks are much the same as the mica schists but contain a higher proportion of quartz and less feldspar and mica.

Hornblende Schists and Gneisses

Two sorts of dark-green hornblende-rich rock are present in the second fault slice. One is medium-grained calcareous hornblende gneiss and the other is fine-grained with a poor schistosity.

The *calcareous hornblende gneiss* forms a layer 50 to 200 feet thick between the Lakeshore fault and the lower Ainsworth limestone. A layer of rusty-weathering mica schist ranging from a few feet thick near the Lakeshore mine to more than 100 feet thick near Mile Point separates the hornblende gneiss from the limestone. The gneiss is a medium- to coarse-grained rock composed mainly of hornblende altered to chlorite and biotite with interstitial plagioclase and calcite. Lime-rich lenses and pods of crystalline white marble produce a crude foliation and lineation, and locally outline minor folds.

The *fine-grained hornblende schists* occur as thick continuous layers near the western side of the second fault slice and as smaller lenses to the east. They extend southward beyond the map-area and to the north are truncated by the Josephine fault about a mile south of Fletcher Creek.

These hornblende schists are fine-grained and dark green with a poor schistosity. They commonly weather a rusty brown, particularly near the Josephine fault, where they contain pyrrhotite. Near the centres of the thickest layers, as on the Glengarry property and south to Coffee Creek, and also west of the Highland mine, the hornblende schists grade into fine- and medium-grained hornblende-plagioclase gneisses. Most commonly the hornblendic rocks are interlayered with the quartzites, but some are found in the mica schists. The hornblende schists are mainly concordant with the enclosing rocks and are regarded as sill-like mafic intrusions.

In thin-sections of the hornblende schists of the second fault slice, hornblende and plagioclase are the main constituents. Biotite, chlorite, calcite, epidote, apatite, and sphene are present in some sections in minor amounts. The plagioclase is andesine or labradorite, which may or may not be twinned. The hornblende is in subhedral well-formed crystals which locally have ragged edges.

CORRELATION

Rocks of the second fault slice are correlated with the Milford and Kaslo Groups that outcrop widely northwest of Kaslo. South of Milford Peak the rocks of both groups pass along the eastern slope of Mount Buchanan and continue southward into the third fault slice of the Ainsworth-Kaslo area (*see* Fig. 2). The limestones, quartzites, and grey mica schists of the second fault slice, just described, closely resemble rocks of the Milford Group, particularly those near Kaslo. The stratigraphic succession within the Milford is uncertain because of structural complexities, but the following section taken from Cairnes (1934, p. 38) shows the sequence of rocks as they are exposed near Milford Peak. The layers dip to the west and are considered by Cairnes to be right side up. The thicknesses are maximal and measured without regard for internal repetitions, which probably are abundant.

	Approximate Thickness (Ft.)
Slate, platy argillite, limestone, quartzite	2,550
Chert, cherty greenstone, andesite, porphyrite	470
Argillite, slate, limestone, cherty greenstone	1,155
Limestone	310
Slate	100
Total	4,585

A very similar general distribution of rocks occurs within the second fault slice of the Ainsworth-Kaslo area, but in it only rocks below the uppermost slate are found. The limestones are the Ainsworth, Krao, Dictator, etc.; the chert is the micaceous and limy quartzite found in the southern part of the Ainsworth camp, the interlayered slate and argillite are the grey fine-grained mica schists, and the greenstones are the fine-grained hornblende schists in the eastern parts of the second fault slice.

The Kaslo Group (formerly series) near Milford Peak lies west of the Milford and consists of a thick mass of basic volcanic rocks forming a series of prominent high peaks extending at least 20 miles northwest of Kaslo. Volcanic flows, pyroclastic rocks, and intrusive members are recognized by Cairnes (1934, pp. 44 and 45) within the group in its widest exposures northwest of Kaslo. South of Milford Peak the Kaslo intrudes the Milford in a series of thick concordant sills which are well exposed along the eastern slope of the Blue Ridge. They intrude cherty and slaty rocks, lying parallel to the prominent west-dipping bedding planes. Dense aphanitic margins of the sills grade into a central fine- to medium-grained part. They are composed of hornblende, albite, chlorite, and epidote and are clearly meta-andesite, basalt, or diabase in a low grade of regional metamorphism. They resemble closely the interlayers of hornblende schist in the quartzites and mica schists of the second fault slice in the Ainsworth-Kaslo area, with which they are correlated.

LITHOLOGIC SUCCESSION

Though the detailed stratigraphy of the rocks within the second fault slice is not known and the formations are very lenticular, it is possible to define a lithologic succession which is consistent over a limited area. Two successions, one near the Florence mine and one in the Highlander-Hot Springs area described by Eastwood, are shown in the following table:—

LITHOLOGIC SEQUENCE SECOND FAULT SLICE

Highlander-Hot Springs Area		Names Used in This Report	Kootenay Florence Mine Area	
Lithology	Thickness (Ft.)		Lithology	Thickness (Ft.)
		Josephine Fault.		
Fine-grained hornblende schist; minor quartzite.		Interlayered Kaslo and Milford Groups.	Fine-grained hornblende schist.	
Micaceous quartzite.	90–400		Micaceous quartzite.	0–100
			Banded limy quartzite.	50
		Libby.	Light-grey dolomite.	10– 30
Quartzose and carbonaceous limestone.	0–180	Dictator limestone.	Platy micaceous quartzite and quartz mica schist.	
Silver schist.	100–470		Fine-grained biotite hornblende schist.	500–700
Hornblende schist.	0–800	Kaslo Group.		
Greywacke.	440–700		Fine-grained grey mica schist; minor hornblende schist.	
Phyllite.	0– 10			
Quartzose limestone.	20– 40	Upper Ainsworth limestone.	Grey crystalline limestone.	0–200
Phyllite.	120			
Quartzose limestone.	30		Fine-grained grey mica schist.	200–300
Phyllite.	0– 75			
Quartzose limestone.	200–350	Lower Ainsworth limestone.	Grey banded crystalline limestone.	250–350
Platy mica schist.	120±		Fine-grained quartz mica schist.	2– 30
Hornblende gneiss.	60		Hornblende gneiss.	50–100
		Lakeshore fault.		
Quartzite and garnet mica schist.		Princess Formation.	Garnet quartz mica schist.	

STRUCTURE

Most of the rocks of the second fault slice have a well-defined foliation that dips at moderate angles to the west. The foliation appears parallel to formational boundaries, many of which have been carefully traced for miles along the strike and, in underground workings, for more than 1,000 feet down the dip.

A fine lineation consisting of trains of mica flakes and microscopic wrinkles is well marked in most of the mica schists. Lineation is also found in some of the hornblende schists and the marbles. Stereographic plots of the lineation (*see* Fig. 8) show a moderately uniform plunge between north and north 20 degrees west at 5 to 15 degrees.

Careful mapping of distinctive rock units in the western part of the second fault slice south of Ainsworth has disclosed a series of isoclinal folds that cause a systematic lensing out of the formations. These folds are shown in plan on Figure 3 and in diagrammatic section on Figure 4. Small folds related to the larger folds are seen only in the hinge zones north of the Krao mine. The axes of the small folds in this area are parallel to the lineation and plunge on the average north 20 degrees west at 12 degrees.

One fold with hinge near the Krao mine and referred to as the Krao anticline has the Krao limestone in the core. The limestone itself forms an isocline. The limestone ends toward the north on the hinge of the fold about at the point where it is crossed by the road to the United mine. Farther north the hinge zone of the anticline is outlined by two layers of quartzitic rock separated by hornblende schist (*see* Fig.

3). Other isoclinal folds of the same sort can be seen in quartzites enclosed by hornblende schists just west of the Maestro claim, in bluffs near the road to the Eden and Crescent mine, and in the quartzite limestone sequences 1,000 feet west of the highway about a mile south of Coffee Creek. The axial planes of these isoclinal folds dip to the west parallel to the foliation and also parallel to the general attitude of the formations. The axes in general plunge somewhat west of north at 5 to 15 degrees. Although they have been recognized only in the part of the second fault slice south of Cedar Creek, they probably are present throughout its length. Obscure strike faults which may or may not be related to this folding complicate the fold structure. These faults, pinched-out limbs of folds, and fold hinges cause most, if not all, of the lenticular character of the rock units.

The isoclinal folds are the oldest folds recognized and tentatively are correlated with the Phase I folds of the Duncan Lake area (*see* p. 62). The Phase I folds are folded at different places by two sets of moderately open folds, one with gently plunging axes and the other with steeply plunging axes. The gently plunging folds are called Phase II folds, and the steeply plunging ones Phase III folds. The Phase II folds closely resemble Phase II folds in the Duncan Lake area, with which they are tentatively correlated. Phase III folds are probably of more local origin.

Phase II folds in the second fault slice are small and are found at only a few places. In general they are similar folds with axial planes dipping at low angles commonly to the west and axes plunging gently to the north. Characteristically these folds have rounded hinges and are the shape of a letter S or reversed N (И) in cross-section looking north down the plunge. In the canyon of Woodbury Creek just west of the Fletcher Creek logging-road, several folds of this sort are outlined by sills of felsite. In the sketch (Fig. 7), the axes of the folds plunge about 5 degrees to the north and are parallel to lineations in both the felsite and the enclosing calcareous mica schists.

Phase III folds are most abundant in quartzites and calcareous argillites near the Libby limestone and on strike to the north, but are found locally throughout the second fault slice. They consist of open to almost isoclinal folds with rounded hinges and a moderately steep plunge. In general they measure a few inches to a few feet across. The plunge, shape, and attitude of the axial planes is quite variable even within one outcrop. In general the axes plunge between west and northwest at angles of 15 to 30 degrees, and the axial planes dip steeply to the south. Most of these folds are Z-shaped in plan.

Several strike faults dipping to the west are recognized within the second fault slice, and probably others are present that have not been recognized. Very careful mapping by Eastwood near the Highlander mine has shown that a number of strike faults lying almost parallel to the foliation are present in addition to the vein faults (*see* p. 88). Near the No. 1 portal of the Florence mine a soft sheared zone containing water and gas under high pressure was encountered in drilling and referred to by Cominco geologists as the Western fault. Drilling suggests that the fault dips west more or less parallel to the formations. In the area drilled it is beneath a swampy area which traced northward coincides with the soft lead (*see* p. 19) exposed in the canyon on Woodbury Creek, where it consists of dark-grey to black soft carbonaceous schist containing disseminated pyrite. It is about 500 feet wide and dips 35 to 50 degrees to the west more steeply than the enclosing formations. Lenses of sheared felsite are present within the zone. It is not exposed to the north but probably continues to Fletcher Creek and possibly beyond.

THIRD FAULT SLICE

The third fault slice is bounded on the east by the Josephine fault and on the west by the Gallagher fault, which is well defined north of Woodbury Creek, but is difficult to define farther south (*see* p. 20).

LITHOLOGY

South of Fletcher Creek the third fault slice contains mainly grey knotted schists and fine-grained limestones in a moderate grade of regional metamorphism. North of Fletcher Creek it contains, in addition, green schists, metadiorites, and associated serpentines as well as grey cherts, quartzites, and dark-grey crinoidal limestones. These rocks pass from a garnet grade of regional metamorphism into lower grades to the north.

Grey Knotted Schists

The grey knotted schist includes a variety of fine-grained poorly foliated rocks containing quartz, muscovite, chlorite, and porphyroblasts of garnet and staurolite. Some of the rocks, particularly those relatively rich in quartz, are blocky fine-grained grey micaceous quartzites and argillites. In general the various types grade into one another and have not been distinguished in field mapping.

The schists have poorly defined crenulated cleavage. Bedding cannot be distinguished with certainty. In the quartzites, vague layers a few inches to more than a foot thick marked by parallel joints or slight differences in composition locally may represent bedding. At places they are parallel to thin lenticular layers of limestone.

The matrix of the grey schists is very fine grained. Quartz, muscovite, and chlorite are the main constituents seen in thin-sections. Plagioclase, tourmaline, and opaque carbonaceous material are present in most rocks. Porphyroblasts are most commonly garnets which appear as rounded equidimensional knots, and less commonly staurolite. Rounded prismatic crystals of staurolite commonly one-quarter of an inch and locally more than an inch long are found south of Fletcher Creek, but not north of it. In thin-section, both garnet and staurolite porphyroblasts are composed largely of a fine-grained aggregate of muscovite and minor chlorite, quartz, and rare biotite. Incompletely replaced remnants of garnet are common, but remnants of staurolite are scarce. The crystal form of the porphyroblasts and fine trains of opaque inclusions are preserved even in porphyroblasts in which none of the original mineral remains.

Limestones

Thick but lenticular limestones form prominent ridges and bluffs mainly west of the grey knotted schist. Also layers and lenses of limestone are found locally in the schist. These are a few feet to a few tens of feet thick and extend along strike for hundreds of feet. Only the largest are shown on the map (Fig. 3). The thin limestones and the main limestone formations are fine-grained blue-grey weathering rocks which on fresh surfaces are grey, black, or white with or without distinct banding. Most specimens when broken emit an odour of hydrogen sulphide.

North of Lendrum Creek a thick limestone formation and a thick grey knotted schist formation comprise distinctive units. The limestones probably overlie the schists. South of Lendrum Creek limestone is complexly interlayered with schist and the proportion of limestone in the schist decreases southward. Some of the individual limestone layers in this area have been named. The Star limestone of Schofield (1920, p. 14) and the Buckeye limestone north of Cedar Creek, for example, are poorly defined formations in a complexly interlayered limestone-schist sequence. Probably the interlayering of limestone and schist south of Lendrum

Creek in contrast to the apparently thick limestone and schist formations north of Lendrum Creek results from repetitive folding. The name Star limestone is used in this report for any of the thicker limestones in the third fault slice, all of which may be structural repetitions of one formation.

Green Schists and Phyllites

Green schists and phyllites, metadiorites, and associated serpentines occur in the northern part of the third fault slice. Just north of Fletcher Creek they form a narrow layer which is truncated by the Josephine fault and is infolded with the grey knotted schists on the west and with fine-grained grey schists and limestones on the east. The green schists that occur between Fletcher and Bjerkness Creeks widen northward into an interlayered sequence of greenstones and cherty argillites that continues northward across Kaslo River to the type area of the Kaslo Group on the Blue Ridge (*see* Fig. 2). Between Kaslo River and Bjerkness Creek, many of these rocks are sills of metadiorite ranging from a few feet to a few hundred feet thick. They have aphanitic chilled margins and fine- to medium-grained central parts. Layers of chert, slate, or quartzite, generally thinner than the sills, separate them or occur as inclusions. Masses of aphanitic greenstone with a poor schistosity and poorly defined zones of serpentine are found on both sides of the valley of Bjerkness Creek.

These rocks of the Kaslo Group lie west of cherts, slates, argillites, quartzites, and limestones of the Milford Group that are exposed on the slopes facing Kaslo between Bjerkness Creek and Kaslo River. The Milford cherts, slates, and argillites, which are generally dark or light grey, outcrop on the upper part of the slope and are interlayered with the Kaslo sills. The limestones, in layers up to a few hundred feet wide, are fine-grained dark blue-grey argillaceous rocks locally containing fragments of small crinoid stems. Quartzites lying east of and lower on the slope than the limestones are dense brownish-grey resembling quartzites near Coffee Creek in the second fault slice.

CORRELATION

A correlation of some of the rocks in the third fault slice with the Kaslo and Milford Groups has been made in the foregoing paragraphs. Rocks correlated with the Kaslo Group are continuous with those at the type locality on Blue Ridge. Those correlated with the Milford Group are almost continuous and are lithologically very similar to Milford rocks at the type locality on Milford Peak northwest of Kaslo. The continuity is broken by intrusions of the Kaslo greenstones.

The correlation of the knotted grey schist and of the Star limestone is uncertain, though both are tentatively regarded as part of the Milford Group. At the type locality of the Milford Group a thick succession of slate, platy argillite, limestone, and quartzite lies west of a thinner sequence of chert, limestone, quartzite, and slate (*see* p. 27), and all these rocks are east of the Kaslo greenstones. Between the type locality and the north side of Fletcher Creek, most of the Kaslo Group is intrusive into slates and argillites. It is concluded that intrusives of the Kaslo Group transgress the Milford in this area, gradually stepping westward and upward(?) toward the north through the Milford strata.

Near the type locality the upper argillites and limestones of the Milford are east of the Kaslo Group, but south of Fletcher Creek they are represented by the grey knotted schists and the Star limestone and are west of the Kaslo greenstones. The Star limestone, judging from the structure, probably overlies the grey knotted schists, and the quartzites, limestones, and argillites north of Bjerkness Creek probably are stratigraphically beneath the knotted schists (*see* Fig. 3).

It has been shown in the preceding section (p. 27) that rocks of the second fault slice probably belong to the lower part of the Milford Group, and it is suggested in the following section (p. 33) that greenstones in the fourth fault slice that overlie the Star (No. 1) limestone are effusive and pyroclastic parts of the Kaslo Group in a true stratigraphic position.

STRUCTURE

In general the prominent foliation and layering of rocks in the third fault slice dip to the west at moderate angles. In the green schists and the grey knotted schists this foliation is a poorly defined schistosity. In the limestone it is a more or less well-marked black or grey banding. In some outcrops this foliation is folded on axes with a low plunge to the north so that locally it is vertical or dips to the east.

Lineation in the grey knotted schists consists of a poorly defined wrinkling of the schistosity and locally a vague alignment of porphyroblasts. In general it plunges to the north at low angles.

Small folds are common in the limestones and green schists and less common in the grey knotted schists. They are similar folds with axial planes dipping at low to moderate angles to the west and axes plunging gently to the north. They are like Phase II folds in other parts of the area and are tentatively correlated with them. Most commonly in cross-section they are the shape of a reversed N (И) the long limbs dipping to the west and the short limb between the long limbs dipping at low angles either to the east or to the west. In the limestones and green schists the schistosity and banding is folded together with the layers. In the knotted schists the westerly dipping schistosity locally cuts across quartzitic layers at the hinges of Phase II folds.

Small Phase I folds are seen rarely. A few are exposed in quartzitic layers in the knotted grey schists on the north side of Woodbury Creek. They are isoclinal with rounded hinges and gently plunging axes. Larger Phase I folds are outlined by the base of the Star limestone in this same locality. This limestone contains an isoclinal anticline lying west of a syncline (*see* Fig. 4, section D-D′) both with axial planes broadly folded and dipping generally to the west. Other isoclinal folds are inferred from the pattern of the limestone layers south of Lendrum Creek and also south of the Star mine, but the folds themselves are not seen in the field and the exposures and detail of mapping have not permitted their discovery.

FOURTH FAULT SLICE

The fourth fault slice lies between the Gallagher fault on the east and the Nelson batholith on the west. It is a belt of complex geology containing a wide variety of rocks in a low grade of regional metamorphism intruded and locally metamorphosed by marginal facies of the batholith. The principal rock types are dark- and light-grey limestones, dark-grey to black and purplish-grey argillites, fine-grained grey dolomite, and several sorts of green phyllites.

LITHOLOGY

The limestones and dolomites of the fourth fault slice are fine-grained light- or dark-grey generally massive rocks. They are mostly fetid. White and dark- or light-grey banded limestones are fairly common, and distinct formations of white limestone and of dark blue-grey thin-bedded limestone and argillaceous limestone (unit 5*c*) can be recognized. Near the granitic rocks between Lendrum and Fletcher Creeks the limestones contain small amounts of metamorphic silicates and are locally medium to coarse grained. The dolomites are distinguished from the limestones by their weathering characteristics and reaction to dilute hydrochloric acid. On weathered surfaces the dolomites are angular, highly fractured, and commonly chalky or buff, whereas the limestones are pitted, rounded, and blue grey or white.

The limestones and dolomites are commonly associated with grey argillites, which occur either as thin lenses too narrow and complexly folded to map or as thicker distinct formations. One of the thicker layers of argillite (map unit 5*b*), which has been traced from Woodbury Creek to Fletcher Creek, is a purplish-grey hornfelsic rock essentially lacking foliation of any sort. Other argillites, widely distributed throughout the fault slice (units 3*i* and 5*a*) and commonly found between green phyllites and limestones, are dark grey, black, and generally well cleaved. They commonly contain lenses of blue-black limestone.

Two volcanic sequences are present in the fourth fault slice. One is relatively massive green phyllite (map unit 4*c*) forming a lens north and south of lower Fletcher Lake. It is uniform olive green poorly foliated chlorite-hornblende-epidote phyllite without primary structures that would indicate origin. The other volcanic sequence (map unit 4*d*) contains tuffs, thin-bedded chert, and siliceous argillite as well as sills or flows of chloritic phyllite. The sequence is characteristically well foliated, showing both primary layering and superimposed cleavages and schistosity. Well-defined minor folds are present in many outcrops. These rocks form a narrow probably synclinal lens extending north from near the Skyline mine to Lendrum Creek near the Nelson granite. They are found again in isolated areas north of Lendrum and Woodbury Creeks.

CORRELATION

Despite complexities of the structure of the fourth fault slice, it has been possible to reconstruct a stratigraphic succession. Though composite, and closely dependent on the structural interpretation, the succession given in the following table seems to apply throughout the fourth fault slice within the Ainsworth-Kaslo area.

Group	Map Unit	Thickness (Ft.)	Lithology
Slocan Group	5*d*		Grey and white limestone locally crinoidal, minor argillite.
	5*b*	100–400	Purplish-grey hornfelsic argillite.
	5*d*		Grey and white fine-grained limestone, minor dolomite.
	5*c*		Interlayered blue-grey to black crinoidal limestone or dolomite and black argillite.
	5*e*		Light- and dark-grey massive fine-grained dolomite.
	5*d*		Grey and white fine-grained limestone.
	5*a*		Dark-grey slate and argillite, minor limestone.
Kaslo Group	4*d* and 4*c*	Several hundred	Green phyllite and interlayered green phyllite, tuff, greywacke, chert, etc.
Milford Group	3*i*	Few hundred	Dark-grey to black argillite, slate, or phyllite, thin limestone lenses.
	3*k*	Several hundred	Fine-grained grey fetid limestone, No. 1 limestone.

Schofield (1920, p. 16) has named the No. 1 limestone from the No. 1 mine which is within the fourth fault slice. Present mapping and understanding of the structure indicate that it is underlain by grey to black argillites (map unit 3*j*) and overlain by grey argillite and argillaceous limestone (map unit 3*i*), which in turn is overlain by volcanic and sedimentary rocks of the Kaslo Group (map unit 4*d*). The No. 1 limestone is fine-grained, grey, dark-grey, and white, more or less well-banded fetid limestone lithologically similar to some of the other limestones in the fourth fault slice and to the Star limestone of the third fault slice. Locally as in the No. 1 mine the limestone contains narrow beds or isoclinal infolds of black argillite. On the basis of present structural interpretation, the best correlation is that the No. 1 and the Star limestones are equivalent and repeated by folding and faulting. The argillite overlying the No. 1 limestone (map unit *3i*) is taken to be the uppermost formation in the Milford Group and is overlain by the lowermost volcanic rocks of the Kaslo Group with apparent conformity.

Some of the limestones and dolomites of the fourth fault slice contain fragments of star-shaped crinoid stems. These are particularly abundant in map unit *5c* where it is exposed near Bjerkness Creek and on the ridge between Fletcher and Woodbury Creeks. They are also present in limestone and dolomite west of this unit between Fletcher and Woodbury Creeks, and one occurrence at Woodbury Creek bridge near the Silver Coin property is marked as a fossil locality by Schofield (1920, map 1742). On the north side of Bjerkness Creek, rocks of unit *5c* contain also brachiopods and gastropods. A single specimen of a possible ammonite was found on the ridge 1 mile south of lower Fletcher Lake. Collections from these fossiliferous limestones and dolomites were sent to the Geological Survey of Canada for identification. Though none of the fossils was positively identified, it was concluded that the rocks are probably Triassic. Collections of similar fossils are described by Cairnes (1943, p. 60) from rocks of the Slocan Group. Many of the rocks of the fourth fault slice are traditionally regarded as part of the Slocan Group, though the abundance of limestone and dolomite is in marked contrast to the dominant black argillite-slate lithology of most of the group elsewhere. The problem of the age of the Slocan Group (and of the Milford) is discussed by Little (1960, p. 56). The present study does not add to our knowledge of the age, but has shown that the structure is exceedingly complex and that no valid interpretation of the limited amount of palæontological data is possible until the structure is understood. In the stratigraphic table (p. 33), rocks above the green phyllites are correlated with the Slocan Group on the basis of the lithologic succession in which they are found and the fossil assemblages, particularly the star-shaped crinoid stems. The green phyllites are thought to belong to the Kaslo Group. They are interpreted as extrusive volcanic facies of the sill-like intrusives of the second and third fault slices together with sedimentary and pyroclastic rocks and minor intrusions. If this correlation is correct, they are in true stratigraphic position and the overlying rocks form the lowermost part of the Slocan Group.

STRUCTURE

The fourth fault slice is complexly folded, faulted, and intruded by small granitic bodies and by the Nelson batholith. The oldest structures recognized are isoclinal folds with curved axial planes and gently plunging axes. They have been folded by more open structures with a low plunge and with axial planes dipping at low to moderate angles to the west. These two types of folds resemble the Phase I and Phase II folds in the fault slices to the east with which they are tentatively correlated. In the fourth fault slice they are truncated by northerly trending faults and, near the Nelson batholith, are further buckled, faulted, and contorted.

The isoclinal Phase I folds can be seen in many outcrops and at a distance in cliffs on some of the higher peaks. Several of the largest have been discovered in mapping. Small folds are common in the limestones, some of the best exposures of which are on the logging-roads south of Cedar (*see* Fig. 27) and Lendrum Creeks and in the cliffs southwest of lower Fletcher Lake. These folds have a low plunge to the north and folded axial planes. In thin-bedded slaty, cherty, and volcanic rocks (map unit 4*d*) on the north side of upper Cedar Creek, repeated small isoclines have essentially vertical axial planes (Plate VIII). The same folds in argillaceous rocks north of Lendrum Creek have broadly folded axial planes with a low dip to the north and northeast.

A large syncline in dolomite and limestone exposed on the hills north of lower Fletcher Lake is illustrated in Plate VI. Recessive grey limestone and dolomite occupy the trough and light-grey-weathering limestone defines the limbs. The fold is seen best from a distance because in the outcrop the hinge zone is tightly pinched and not well exposed. The axial plane is broadly curved on a Phase II fold with a low-plunging axis and a low west-dipping axial plane.

Phase II folds are well displayed on the north side of Bjerkness Creek on a burned-off hillside of limestones, dolomites, and argillites. The folds, which are truncated by a number of faults, are illustrated in Plate XIII and Figure 4 at the western end of Section A-A′. The axes of the folds plunge at low angles to the north, and the axial planes have a low dip to the west. Steeply dipping northerly trending faults appear to have dropped the folds down on the west and hence to have preserved the same rock units and folds over a relatively great east-west distance on the hillside. The fault zones contain graphitic schist and brecciated calcareous rocks.

Large second folds, broken by faults like those on the slope north of Bjerkness Creek, have been found also to the south but are not as well exposed. In the valley of Fletcher Creek between lower Fletcher Lake and the Gallagher fault, argillites, limestones, and dolomites are folded on axes plunging to the north by relatively tight similar folds with low west-dipping axial planes. Several Phase I isoclines are folded by these Phase II folds, and both sets of folds are displaced by northerly trending faults. The same patterns of folding have been determined in detailed mapping in the No. 1 and Silver Hoard mine areas (*see* Fig. 27), but poor exposures obscure their continuity.

Deformation related to the emplacement of the Nelson batholith can be recognized at distances ranging from less than 500 feet, near Coffee Creek, to more than a mile from the granitic contact in Woodbury and upper Fletcher Creeks. In the latter area, Phase I and Phase II folds have been buckled as indicated by a change in the plunge of their axes. Near Woodbury Creek and as far north as the ridge south of Fletcher Creek the folds plunge northward at various angles. Farther north in the valley of Fletcher Creek they plunge at moderate to steep angles to the south. The azimuth of the fold axes remains fairly constant and the axial planes of Phase I folds in general dip steeply. Near Krao Creek minor folds plunging northwest and west, which are not recognized elsewhere in the area, are thought to be related to the granitic rocks. Near Coffee Creek a westerly dipping crushed zone forms the eastern margin of the batholith. It appears to pass northward into the rocks of the fourth fault slice and may in part join the Gallagher fault (*see* p. 20).

REGIONAL METAMORPHISM

The Ainsworth-Kaslo area contains rocks ranging from a low to a high grade of regional metamorphism. The kyanite and sillimanite zones are near Kootenay Lake, and the grade decreases westward away from the lake. The map-area is on the western side of a northerly trending metamorphic belt of regional extent. This belt is not shown on the regional geological maps of the district, but maps prepared by Crosby (1960) which include part of the Ainsworth-Kaslo area show metamorphic isograds. These are based on the first appearance with increasing metamorphism of the classic index minerals biotite, garnet, staurolite, kyanite, and sillimanite. In the present study only the kyanite and garnet isograds determined from the megascopic appearance of these minerals have been mapped (*see* Fig. 2). These isograds trend northward and by reconnaissance work have been extended beyond the map-area. The garnet isograd has been linked with the one determined in the Duncan Lake area.

Although the regional picture is still quite incomplete, it appears that the metamorphic zones in the Ainsworth-Kaslo area are part of an elongate metamorphic belt trending northward along the Purcell trench for 75 to 100 miles. The southern and northeastern limits of the belt have not been carefully studied. Rocks of the highest grade are exposed mainly on the east side of Kootenay Lake from north of Kaslo to Crawford Bay, and they extend southward into the hills west of the main lake and southeast of the West Arm (*see* Fig. 1). Rocks in the biotite and higher grades form a belt probably at no place more than 15 miles wide from east to west and at least 75 miles long.

Within the Ainsworth-Kaslo area the metamorphic zones for relatively long distances parallel the formational trends. Traced far enough, however, they are found to transect the formations. The zones appear to be offset by the Josephine fault (*see* p. 19) and may also be displaced by other northerly trending faults.

Rocks of the highest metamorphic grade which are near Kootenay Lake are quartz-mica schists and gneisses containing kyanite and sillimanite. These index minerals, found only on the lake-shore south of Coffee Creek, in the bays south and north of Woodbury Point, and north and south of Kaslo, suggest that the kyanite isograd trends northward and is close to the lake.

These rocks pass westward into those in which garnet and staurolite are the key minerals in the argillaceous formations. Most of the mineralized zones of the Ainsworth camp are in rocks of the garnet and staurolite grade. In most of the map-area, rocks of this grade continue westward through the third fault slice. The garnet isograd from near Coffee Creek to Fletcher Creek follows the eastern edge of the fourth fault slice, but whether or not the isograd is offset by the Gallagher fault has not been determined. Within the third fault slice the rocks pass northward into the biotite and muscovite grades less than a mile north of Bjerkness Creek. North of this point these rocks are in contact on the east across the Josephine fault with those of the garnet grade in the first and second fault slices. Reconnaissance to the north indicates that the garnet isograd runs obliquely across these two fault slices between the north slope of Kaslo River and lower Schroeder Creek (*see* Fig. 2). Probably the garnet isograd is offset on the Josephine fault from north of Bjerkness Creek to the north slope of Kaslo River.

Characteristic rock types in each of the fault slices are briefly described in the foregoing parts of this chapter. Assemblages of metamorphic minerals from widely scattered parts of an area including and lying south and east of the Ainsworth-Kaslo area are listed by Crosby (1960). In the present work, routine studies of thin-sections show contrasting metamorphic minerals and textures between each of the zones, the most outstanding of which are described in the following paragraphs.

In the grey knotted schists of the third fault slice, porphyroblasts of both garnet and staurolite largely altered to sericite, chlorite, and quartz are common and are found widely south of Fletcher Creek. North of Fletcher Creek, only garnets are found, and they diminish in size to the north before the schists pass into dark-grey very fine-grained carbonaceous phyllites and argillites of the biotite and muscovite grade.

Greenstones of the Kaslo Group in the lowest metamorphic grades contain principally hornblende, epidote, plagioclase, and chlorite. The plagioclase is untwinned albite. By contrast, in the higher grades, the plagioclase is andesine or labradorite, and epidote and chlorite are rarely present. Much of the plagioclase is clear and not twinned, but in the highest grades good albite twinning is common and some crystals are slightly zoned.

Small amounts of tourmaline and apatite are found in most of the metasedimentary rocks. They occur as well-formed crystals which become larger and more clustered with increasing grade. Mica schists in the kyanite zone on Woodbury Point contain lenses several inches long of coarse-grained thin black tourmaline crystals.

Rocks of the Princess and Early Bird Formations (*see* p. 21), mapped only in the garnet and higher grades of metamorphism, contrast with those of the Index Formation north of the map-area. The Princess and Early Bird Formations contain fine- to medium-grained lustrous schists and gneisses. In addition to quartz, biotite, and muscovite, they commonly have porphyroblasts of garnet and locally of staurolite and kyanite. In thin-section plagioclase is andesine and labradorite or well-twinned calcic labradorite in rocks containing calcite. In addition, minor amounts of potash feldspar, scapolite, clinozoisite, sillimanite, and tremolite are found in some sections as well as accessory tourmaline, apatite, and pyrrhotite.

With decreasing metamorphic grade these rocks become fine-grained dull-grey schists with or without porphyroblasts of garnet and locally staurolite. Grey schists with porphyroblasts only of biotite are found north of Schroeder Creek in the Index Formation. The Princess and Early Bird Formations grade northward into grey carbonaceous fine-grained schists and phyllites in which quartz, muscovite, chlorite, and albite or oligoclase can be identified under the microscope.

INTRUSIVE ROCKS

Four principal groups of intrusive rocks occur within the Ainsworth-Kaslo area. These are, in order of decreasing geological age, sills and lenses of fine-grained granite, granite pegmatite, the Nelson batholith, and lamprophyre dykes and sills. The Nelson batholith is a large mass west of the map-area, and only the eastern margin is described in this report. The granite pegmatites, although widespread on the eastern side of Kootenay Lake and south of the map-area, are found only locally within the area in rocks of the highest metamorphic grade near the lake.

GRANITIC SILLS

Fine-grained light-coloured granitic sills and lenses are present throughout the map-area and extend beyond it. They are described by Schofield (1920, p. 19) in the Ainsworth camp as gneissic granite and referred to by Rice (1941, p. 37) as the Ainsworth granitic sills. Crosby (1960) includes them with the pegmatite in a map unit called the Kootenay Intrusives, which is distinct from the Nelson Intrusives but related to them. The same sort of sills in the Duncan Lake area (*see* Fyles, 1964, p. 36) are referred to as felsite. Their distribution is shown on Figure 2. The granitic sills in the Ainsworth-Kaslo area have been described by Armour-Brown (1964).

Most of the granitic sills in the Ainsworth-Kaslo area are blocky fine-grained or porphyritic light-coloured rocks with rusty fractured surfaces. They form sills parallel to the most prominent foliation in the enclosing metamorphic rocks. Most commonly they are a foot to several feet thick, but sills 20 to 50 feet thick are not uncommon, and one sill, between Woodbury Point and Fletcher Creek, is more than 500 feet thick, and another, on Woodbury Point, is as much as 150 feet thick. Granitic sills are scattered throughout the area, but those on Woodbury Point are part of a swarm extending north beyond Kaslo.

Granitic sills a mile or so west of Woodbury Point bulge into a series of lenses, four of which, in the second fault slice, cross Woodbury Creek and extend north for almost 2 miles following approximately the same layer of hornblende schist. The contacts of the lenses are sharp and concordant, and the thickest parts taper along strike into one or more thin sills. The largest granitic sill in the area, called the Krao sill, extends south about 2 miles from near the No. 1 mine. It almost joins the Nelson batholith at its southern end, but in surface exposures is separated from it by a septum of argillaceous hornfels.

In the field these blocky granitic rocks stand out as cliffs and prominent hills, such as the bluffs on the highway near Coffee Creek and north of Fletcher Creek and a 3,000-foot knoll north of Woodbury Creek. The rocks themselves have a moderately well-developed lineation and a poor foliation produced by trains and clusters of micas or locally amphiboles. The lineation plunges at low angles mainly to the north and is parallel to the most pronounced lineation in the enclosing metamorphic rocks. The foliation is parallel to the sill margins and to the schistosity of the enclosing rocks. Locally the sills are folded on axes that plunge parallel to the lineation. The style of the folds is similar with rounded and thickened hinge zones which at places show a poor axial plane cleavage. Only minor folds have been found, and they are the shape of a reversed N (И) in cross-section looking down the plunge, with axial planes dipping to the west at low to moderate angles.

Boudinage is common in the thinner sills. The necklines, or places where the sills are pinched, plunge to the west down the dip of the layers and cause a warping of the lineations that lie on the surface of the sills.

Under the microscope the granitic sills show a wide range in composition and texture. Both porphyritic and uniformly fine-grained rocks are common. The principal minerals are potash feldspar (microcline and microperthite), plagioclase (oligoclase and andesine), and quartz. Biotite, muscovite, hornblende, epidote, garnet, chlorite, sericite, pyrite, sphene, and apatite are present in amounts generally totalling less than 10 per cent but locally amounting to more than 20 per cent of the rock. Most of the rocks are quartz monzonite, but some are granite, syenite, or quartz diorite.

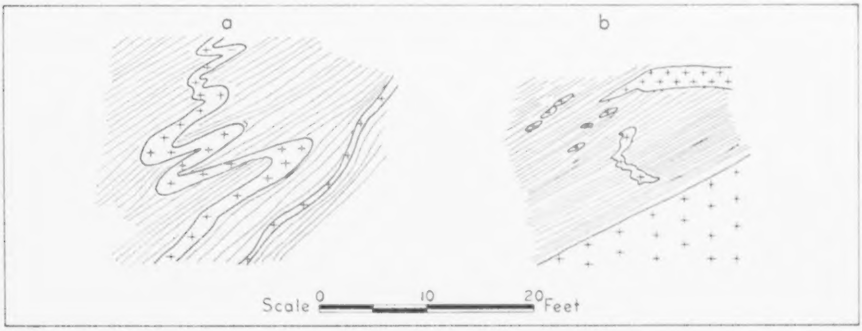


Figure 7. Sketches of folded granitic sills seen in profile looking north.

From the megascopic features of the sills it is concluded that they were intruded late in the second phase of folding. Lineation found in essentially all the sills and minor folds found in a few of them resemble lineations and folds of Phase II structures. At a few localities folded sills are adjacent to or enclosed by sills that are not folded. The sills all look the same, but the folded sills must have been emplaced before the unfolded ones (*see* Fig. 7). None of the larger Phase II folds is outlined by any of the sills. It is suggested that emplacement of the sills began late in the second phase and continued after this phase of deformation was complete. Subsequent deformation, including the third phase of folding, produced boudinage and cataclastic structures and crushing of feldspar and biotite crystals found in many specimens and thin-sections.

Sharp contacts, locally with an inconspicuous " chilled " aphanitic margin and transgressive and dilatant relationships with the wallrocks, are evidence that the majority of the sills are intrusive. They appear to have been emplaced by a passive process under conditions in which the wallrocks were in a state of relative tension perpendicular to their foliation planes at the time of emplacement. Gradational contacts described by Eastwood (1951, p. 147) near the mines south of Ainsworth and local replacement dykes without dilatant offsets found in the highest grades of metamorphism near Coffee Creek indicate that some rocks of the composition of the sills were formed by metasomatism.

Critical evidence that would indicate the age relationships between emplacement of the sills and the regional metamorphism has not been found.

NELSON BATHOLITH

The eastern contact of the Nelson batholith has been included in this study because the granitic rocks form a logical western margin of the map-area. The batholith itself is one of the major tectonic elements of the Kootenay arc (*see* Fig. 12) and is one of two major batholiths lying within the concave part of the arc. The batholith outcrops over an area of more than 900 square miles extending westward from the Ainsworth-Kaslo area almost to Slocan Lake and southward from near the latitude of Kaslo to south of the west arm of Kootenay Lake. Cairnes (1934, pp. 61–68) has described the northern part of the batholith and carefully mapped its northern contact with rocks of the Slocan Group. Little (1960) has mapped all but the eastern contact, which occurs within the Nelson east-half map-area of Rice (1941). Reesor in recent studies (*see* Gabrielse and Reesor, 1964) has restricted the area of the Nelson batholith, excluding from it gneisses along Slocan Lake and in the Valhalla Mountains that are now regarded as part of the Shuswap metamorphic complex.

The eastern contact of the batholith in the Ainsworth-Kaslo area runs somewhat west of north, gradually transecting structures and rock units in the adjacent metamorphic sequence. It is marked by a number of wedge-shaped apophyses that range from a few tens of feet to more than 1,000 feet thick and extend as much as a mile from the batholith into the wallrocks. The apophyses trend northward and are steeply dipping, probably more or less parallel to the main trend of the batholithic margin.

Nelson granite is typically a porphyritic medium-grained granitic rock with phenocrysts of potash feldspar commonly up to 2 inches long. Although this is the commonest rock, other varieties are found within the batholith (*see* Gabrielse and Reesor, 1964, p. 118; Cairnes, 1934, p. 61; Little, 1960, p. 83). As described by Reesor, rock types present in the Nelson batholith " vary from hornblende-biotite granodiorite, typically containing large megacrysts of potash feldspar, to biotite granodiorite, and leucoquartz monzonite. . . ."

The porphyritic facies extends to the eastern margin of the batholith in the Ainsworth-Kaslo area, but toward the margin the phenocrysts become smaller and in the area studied are generally less than an inch long. Porphyritic granodiorite extends into some of the apophyses and is found also in the southern end of the Krao sill. In large apophyses north of Lendrum Creek and in some small ones near Cedar Creek the porphyritic rocks grade into medium and then into fine even-grained granites and syenites.

In general the granitic rocks near the contact are massive or very poorly foliated, but near Coffee Creek there is a strong foliation and the rocks resemble a facies of the batholith described by Cairnes (1934, p. 62) as crushed porphyritic granite. The zone of strongest foliation is adjacent to the contact and grades westward into poorly foliated or massive porphyritic quartz monzonite about 1,000 feet from the contact. The foliation dips westward and steepens from about 30 degrees on the lower part of the slope north of Coffee Creek to more than 60 degrees at the top of the slope. A poor lineation plunges northward at less than 10 degrees. The crushed zone extends south beyond the map-area (*see* Crosby, 1960, p. 149) and ends north of Coffee Creek, where the contact turns irregularly to the northwest. Only local zones of crushed granitic rock are found along the margin of the batholith and in the apophyses to the north, and it is concluded that the shear zone passes into the wallrocks north of Coffee Creek. A strong gneissic banding in the southern part of the Krao sill and irregularly contorted metamorphic rocks in the hangingwall of the sill support this conclusion. The crushed zone is on strike from the Gallagher fault (*see* Fig. 2).

North of Krao Creek, and particularly north of Woodbury Creek, the wallrocks near the batholith, which are thermally metamorphosed limestones and argillites, are contorted by folds apparently related to intrusion. The foliation near the batholith in general dips steeply and commonly is folded on axes that plunge at moderate to high angles both to the northwest and to the south. Folds of both a concentric and a similar style are found. The axial planes dip steeply and the axes change plunge abruptly. These folds are found within the higher-grade parts of a marginal zone of contact metamorphism.

A zone of contact metamorphism follows the eastern side of the batholith. It is widest north of Woodbury Creek, where rocks showing megascopic signs of contact metamorphism extend almost half a mile from the granite contact. South of Woodbury Creek the zone narrows, and south of Coffee Creek adjacent to the crushed zone it appears to be no more than a few tens of feet wide. The contact metamorphism has been described by Crosby (1960, p. 269) and in an area near upper Fletcher Lake by Templeman-Kluit (1961). In the latter area argillaceous rocks in the lowest grade of metamorphism contain quartz, biotite, muscovite, albite, and epidote, and calcareous rocks locally contain tremolite. Higher-grade argillaceous rocks closer to the batholith contain minor amounts of cordierite, andalusite, and locally hornblende. In the highest grade of metamorphism, garnet and sillimanite are found in the argillaceous rocks, and diopside, garnet, scapolite, and plagioclase occur in the calcareous rocks. Since the batholith transects the zones of regional metamorphism as well as Phase I-Phase II structures, it is concluded that the contact metamorphism is superimposed on the regional metamorphism.

Hornblendite grading into hornblende diorite occurs as lenticular dyke-like masses along the batholithic margin near Woodbury Creek. North of the creek the masses form impressive medium- to coarse-grained outcrops of almost black hornblendites that weather into peculiar rounded shapes. They contain minor amounts of andesine as well as biotite and hornblende. South of the creek they are mottled diorites locally containing minor quartz. One of the lenses north of Woodbury Creek cuts porphyritic rock of the Nelson batholith and has a chilled margin against it. Elsewhere these mafic rocks contain inclusions of granodiorite (*see* Templeman-Kluit, 1961, p. 21) and hence were intruded after consolidation of the batholith.

From this study of part of the eastern contact of the Nelson batholith it is clear that emplacement of the batholith was a complex process extending over a considerable period of time. The marginal zone of complex folding and systematic thermal metamorphism appears to have been one of the earliest features in the emplacement process. Aligned sillimanite crystals suggest that metamorphism and folding occurred together. The wedge-shaped apophyses indicate that the batholith grew by dyking and stoping which may have followed the period of folding and intense metamorphism. The crushed zones near Coffee Creek and local crushing in the batholith and apophyses clearly developed late in the period of consolidation. It is significant that on a regional scale both the eastern and western margins are northerly trending crushed zones dipping inward beneath the batholith. These contrast with northern and northeastern margins between the Slocan and the Ainsworth mining camps where the wallrocks are buckled and metamorphosed (*see* Hedley, 1952, p. 32; Cairnes, 1934).

LAMPROPHYRE SILLS AND DYKES

Lamprophyre sills and dykes are found throughout the Ainsworth-Kaslo area. They are blocky dark-grey brown-weathering rocks in which phenocrysts of biotite and plagioclase are common. Locally phenocrysts of almost black hornblende are present. In one sill east of the Star mine these phenocrysts are several inches long and are accompanied by somewhat smaller phenocrysts of feldspar (*see* Rice, 1943, pp. 47, 86). Study of thin-sections shows that most of the lamprophyres contain plagioclase (andesine and labradorite), pyroxene, and biotite. The crystals generally are well formed and the plagioclase lath shaped, forming a felted mass as a matrix. Olivine, as phenocrysts altered to serpentine and carbonate, is present in some lamprophyres. Most of the lamprophyres are more or less altered to sericite, chlorite, and carbonate. Where cut by or adjacent to veins, they are highly altered to an aphanitic light-green or greenish-grey clay-like mass in which chlorite, sericite, carbonate, and epidote can be distinguished in thin-sections.

The lamprophyres range from less than a foot to more than 15 feet thick, but 1 to 6 feet is the most common thickness. They are mainly sills lying more or less parallel to the foliation and are more abundant south of Cedar Creek than to the north. Details of the attitudes and distribution of six sills in an area near the Highlander mine are given by Eastwood (1951, p. 149). Other lamprophyres are dykes which trend between west and northwest and dip steeply. These dykes are most common in the first and second fault slices and appear to lie in the same fractures as the veins. Both dykes and sills are fractured and offset by the vein faults and are mineralized (*see* p. 51).

CHAPTER III.—SILVER-LEAD-ZINC DEPOSITS

INTRODUCTION

The Ainsworth camp contains more than 50 properties from which silver-lead-zinc ore has been shipped, and many others on which there are showings but from which there have been no shipments. Total production since the first shipment in 1889 has amounted to 763,858 tons of ore, from which 4,373,431 ounces of silver, 94,948,494 pounds of lead, and 16,732,265 pounds of zinc have been obtained (*see* Table 1). Production has come mainly from simple quartz carbonate veins containing shoots or lenses of galena, sphalerite, pyrite, and locally pyrrhotite. Early prospecting and exploration turned up showings that appeared to be scattered and isolated, but continued work showed many of them to be grouped along one vein or vein system or to conform to a more widespread set of fractures. This chapter deals with the main vein systems and describes their characteristic features.

Over the years of exploration in the camp many people have thought that orebodies of the type and size found on the east shore of Kootenay Lake at the Bluebell mine should also be present in the Ainsworth camp. The Bluebell orebodies are galena-sphalerite-pyrrhotite replacements of limestone controlled by fractures apparently of the same regional set as those in the Ainsworth camp. Relatively small amounts of replacement mineralization have been found in the camp, though mineralization very like that at the Bluebell is found on the Lakeshore property in the northern part of the camp and was drilled extensively between 1952 and 1956 by Cominco Ltd. At that time it was known that in general the structure of the enclosing rocks had a profound effect on the localization of ore in the Kootenay arc (*see* Fyles, 1962). It was also considered possible that the structure of the wallrocks in the Ainsworth camp might influence replacement, and it was hoped to determine, in the present study, what effect, if any, the structure of the wallrocks had on replacement in the camp. The study has shown that the old, complex, and subtle structures of the wallrocks seem to be relatively unimportant in controlling mineralization in the camp. Controls of mineralization that do seem to be important, related to the fracture systems, are outlined in this chapter. A parallel is drawn between the Ainsworth and the Bluebell mineralization.

VEIN SYSTEMS

Three fairly well defined vein systems are present in the Ainsworth camp, together with two or three clusters of veins forming poorly defined systems. The well-defined systems from south to north are called the Highlander, the Highland, and the Florence (*see* Fig. 8). The poorly defined systems are the United, south of the Highlander, and the Woodbury Creek veins, north of the Florence. Each system includes a number of veins and a number of properties some of which may be on the same vein. A few scattered deposits are not included in these vein systems, the most important of which is the No. 1 mine. The systems are defined somewhat arbitrarily, and the characteristics of them outlined below bring out general features that are present also in the more scattered deposits.

FLORENCE VEIN SYSTEM

The Florence vein system is along a zone of faulting that in general follows the course of Princess Creek and comes to surface several hundred feet north of it.

The zone extends intermittently from near Kootenay Lake on the Kootenay Florence property to Lendrum Creek on the Silver Glance claim and consists of two main parts—one on the Kootenay Florence property and the other on the Silver Glance.

The fault zone on the Kootenay Florence property strikes in general north 70 to 75 degrees west and dips 45 degrees to the south, forming a zone of crushed rock and vein material commonly up to 15 feet wide. It is a normal fault which in the Kootenay Florence mine has a maximum offset near the lower Ainsworth limestone of about 200 feet to the left. The fault splits and branches, causing a wide variation in offset from place to place. East of the lower Ainsworth limestone one branch with a small offset trends eastward through the Princess and into the Early Bird Formation, and another curves southward probably into the foliation along the Lakeshore fault (*see* p. 19). In passing through the Ainsworth limestone the fault splits, forming two "eyed" or frayed sections that are mineralized to form the main ore zones in the Kootenay Florence mine. On surface to the west where the fault zone passes into hornblende schist at the portal of No. 1 level of the mine, several small faults with a maximum offset of 35 feet are exposed. Farther west the fault zone is discontinuous and appears to break up into a number of small faults, in part continuing northwest and in part curving to the north into the foliation (*see* Fig. 9).

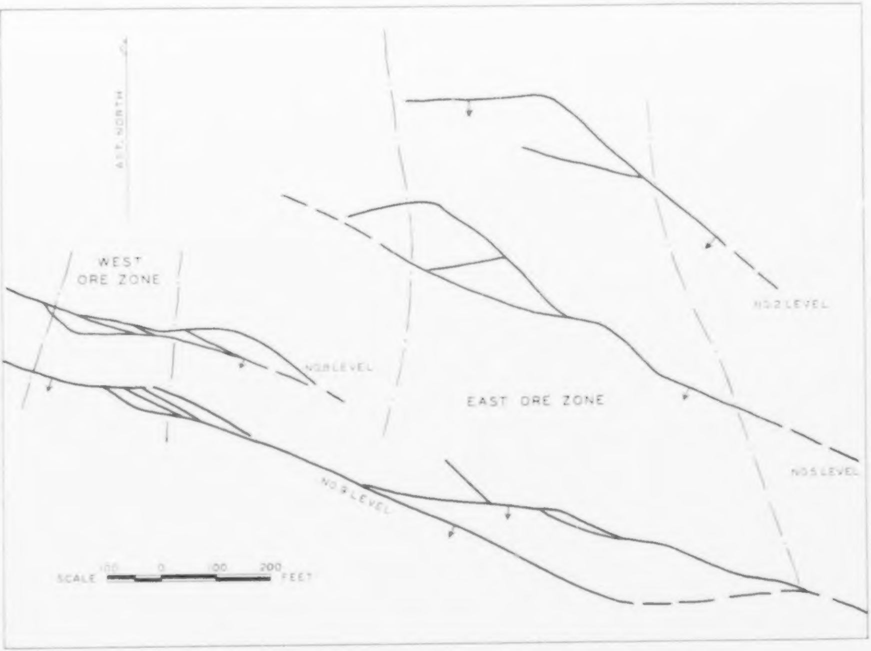


Figure 9. Kootenay Florence vein pattern in the mine workings.

Farther to the northwest a fault in the Silver Glance adit strikes north 60 degrees west, dips 50 to 70 degrees south, and has a left-hand offset of about 200 feet. It is on strike from the fault carrying the Florence vein, but does not join it. Probably it curves southward in going east from the Silver Glance into the foliation before reaching the hornblende schists in the second fault slice.

TABLE 1.—TABLE OF PRODUCTION, 1889–1964

	Tonnage			Gold (Oz.)	Silver (Oz.)	Lead (Lb.)	Zinc (Lb.)	Cadmium (Lb.)
	Year	Mined	Mined, Contents Included Elsewhere[1]					
Amazon	1939–1940	33			346	30,625	4,270	
August	1948–1951	119			1,457	99,181	18,922	
Ayesha	1911, 1949–1952	78			924	39,312	20,518	
Belle Aire	1950	4			8	722	61	
Black Diamond	1949–1964	473[2]	3,010	1	8,276	105,569	29,324	58
Budwiser	1895, 1950, 1954	78	202		15,006[3]	75,411[3]	576	
Buckeye	1953–1954	549	450		1,146	57,105	54,186	
Crown	1962	13			1,253	2,445	1,025	
Crow Fledgling	1937–1960	187	287		800	29,529	22,132	21
Danira	1942, 1956	6	313		51	7,514	635	
Dixie	1951, 1954, 1955	258			524	31,146	3,030	
Early Bird	1914–1916, 1949–1951	165			1,520	127,083	2,787	
Eden Crescent	1916, 1937, 1950–1955	50	10,723		1,308	46,281		
Fergus and Florence M	1907, 1948–1951	265			1,420	18,818	6,569	
Firebrand	1924	16			1,832	3,460		
Gallagher	1889, 1907–1919	250			17,615	31,873		
Grant	1889, 1916–1921	24			9,604	5,489		
Hardie	1919	4			215	4,824		
Hector	1949	12			99	5,187	1,630	
Highland	1890–1927, 1940–1951	98,313			336,272	20,426,691	586,531	
Highland mill	1947–1951			1	2,665	200,173	255,004	1,210
Highlander-Albion-Banker	1889–1910, 1927–1937, 1949–1961	442,410[4]		151	1,028,560	48,720,251	11,529,392	4,345
Jack Pot	1953		388					
Jewel	1937	27			200	15,113		
Kootenay Florence (Laura M)	1912–1929, 1943–1944, 1951–1960	132,406		91	200,376	14,749,616	3,114,592	12,969
Krao	1905–1909, 1920–1924, 1953–1955, 1964	1,658			123,857	404,707	26,709	
Lakeshore Mine (Carey Fraction)	1926, 1927, 1950–1959	1,432			2,874	248,744	144,138	221
Lady of the Lake	1895, 1937	10			820	10,063		
Libby	1907, 1950	33			319	21,296	6,029	
Little Mamie	1921	11			550	11,000		
Little Phil	1895, 1899, 1917–1920, 1955, 1958	612	48		14,290	633,586	1,398	
Lulu	1954	6			113	7,163	440	
Maestro	1907–1923, 1959	2,370			36,973	1,752,242	1,705	
Mile Point	1895	55			4,015	11,000		
Nameless	1950–1953	3,079			4,982	363,796	236,796	
Neosho	1922, 1949–1950	149			3,369	7,733	17,213	
New Jerusalem	1907, 1945, 1952	265	110	8	721	35,773	12,509	
Nicolet-Snelling	1916, 1929, 1950–1952	669			1,493	81,726	42,428	

Noah	1952	385			502	32,400	20,820	
No. 1	1889–1924	40,169		237	1,993,849	298,779		
Sharon	1964	3			31	1,540	146	
Silver Hoard, Dellie	1889, 1895, 1912–1926, 1948–1950	2,137			216,872	159,486	28,782	
Silver Coin	1938–1946	32			4,597	7,111	1,958	
Skyline	1889–1896, 1918–1921	3,027			218,148	4,696		
Spokane and Trinket	1899–1907, 1915, 1929, 1940–1955	2,979	3,923	1	54,805	3,318,055	60,468	
Star and Sunlight	1950–1956	800		1	5,398	144,040	59,542	
Tariff	1896–1899, 1918–1926	1,078	59		35,221	1,480,919	16,176	
Tiger	1928	24		1	186	9,284	5,148	
Townsite	1952	752						
Twin	1949–1953	445			1,254	48,029	29,356	48
United	1906, 1918–1924, 1953–1954	856	400	3	3,069	178,927		
Vigilant	1949–1953	5,163		2	13,615	841,441	369,174	704
Total		763,858		497	4,373,431	94,948,494	16,732,265	19,576
Bluebell	1895–1927, 1952–1964	3,572,696	3,870,350 lb. copper		4,903,829	350,448,630	362,864,347	1,663,965

[1] Shipped mainly to the Yale mill.

[2] Includes some production from Little Phil.

[3] Estimated.

[4] Includes some production from Black Diamond.

The fault zone in many places contains fissure veins of quartz, calcite, siderite, and fluorite with local concentrations of galena, sphalerite, pyrite, pyrrhotite, and minor chalcopyrite. The greatest production of lead and zinc has come from the Kootenay Florence mine where the orebodies are near but do not follow the upper and lower Ainsworth limestones. The fault zone splits in passing through these rocks and the orebodies are associated with the split sections (*see* Fig. 9). In these sections the vein fault strikes more nearly east-west and dips steeper than elsewhere. Displacement of the south side downward and to the east, which is the displacement indicated by the slickensides on exposed fault planes and by the left-hand offset of the formations, would lead to the opening of these split sections and would consequently favour mineralization.

Sulphide mineralization is also found where the fault zone passes through limy lenses in the grey mica schists west of the lower Ainsworth limestone. At one locality exposed on surface, sphalerite, galena, and pyrite extend laterally along a lense of limestone for a few feet from a series of fractures near the Florence vein. Other occurrences of replacement are reported from the upper levels of the Kootenay Florence mine.

Sphalerite and galena also occur along the vein where it passes into the hornblende schist west of the grey mica schist. In the No. 1 level of the Kootenay Florence mine a lenticular vein up to 4 feet thick is present in the hornblende schist and continues for almost 200 feet west of the grey mica schist.

In the third fault slice sulphides are associated with limestones in veins carrying siderite. On the Silver Glance and adjacent claims, the sulphides are found where the fault crosses the Star limestone.

HIGHLAND VEIN SYSTEM

The Highland vein system is exposed mainly on the Highland property just north of Cedar Creek and includes veins on the Buckeye, Josephine, Highland, Maggie, and Libby claims (*see* Fig. 8). It consists of a series of related but discontinuous faults containing quartz-carbonate-sulphide veins.

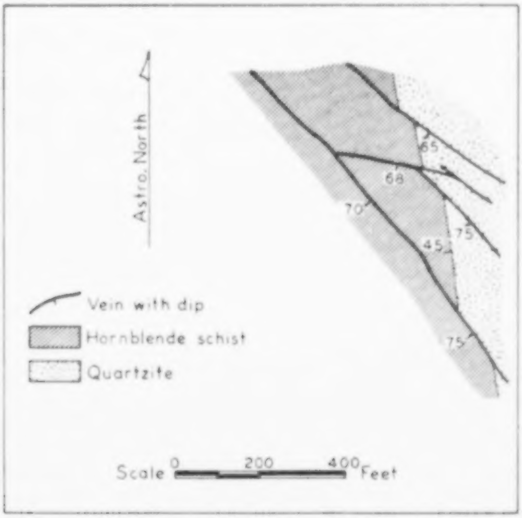


Figure 10. Highland mine vein pattern in No. 1 level.

The vein system is largely in the western part of the second fault slice transecting micaceous quartzites of the Milford Group, dolomite of the Libby member, and hornblende schists of the Kaslo Group. Veins on the Buckeye are in the third fault slice in grey knotted schist and fine-grained grey limestone. In this rock sequence, sulphides are found in the veins near the quartzite-hornblende schist contact and associated with the limestone and dolomite.

The main vein in the Highland mine strikes north 40 degrees west, dips 70 to 75 degrees to the southwest, and is along a normal fault along which the formations, which dip westward, are offset about 100 feet to the left (*see* Fig. 10). A more or less parallel fault 200 feet to the northeast contains the footwall vein, and one or more branching faults between these two contain the middle vein. The middle vein strikes about north 75 degrees west and dips 60 to 70 degrees to the south. Traced to the northwest, the main vein appears to branch; one branch, the Josephine vein, trends to the north, and judging from exposures at the top of the Josephine raise breaks into the Josephine fault (*see* p. 19) in the hangingwall of the hornblende schists. The other branch, called the Highland vein, continues to the northwest toward the Buckeye vein. The fault that contains the Buckeye vein strikes north 55 degrees west and dips 70 degrees to the southwest and has produced an offset of about 15 feet to the left in the main workings, decreasing to almost nothing 100 feet northwest of the Buckeye workings (*see* p. 75). Whether or not it is continuous with the Highland vein is uncertain. The fault containing the Highland main vein also probably splits toward the southeast into a series of in echelon faults on the Maggie and Libby claims. These faults are in quartzite and cross the Libby dolomite. Probably they have a relatively short strike length. Two of them strike northwest and dip 65 to 75 degrees to the south; another strikes north 75 degrees west and dips 60 degrees to the south. They produce a left-hand offset of the formations of a few feet.

The principal mineralization in the Highland vein system is close to the quartzite-hornblende schist contact. The best oreshoots are very close to this contact and were mined principally in the zone of offset where the hangingwall of the vein is hornblende schist and the footwall is quartzite. Consequently the orebodies rake to the west down the formational dip. Quartz with scattered sulphides extends away from the contact, and the main vein has been followed along strike for as much as 1,500 feet. Through most of its length it contains quartz and scattered sulphides, and in general has been stoped for a strike length of about 700 feet, somewhat farther into the hornblende schists than into the quartzites. Beyond the workings, the vein fault is an inconspicuous narrow zone of sheared and crushed rock. The middle and footwall veins have shorter stopes and smaller shoots than the main vein and have not been traced beyond the workings.

On the Buckeye and Libby the ore is associated with limestone and dolomite and has spread out from the veins by replacement of the limestone. Oreshoots rake to the west with the formations and following the vein the shoots extend 10 to 15 feet along the formations and about the same distance along the vein, on the Buckeye near the hangingwall of the limestone and on the Libby completely crossing it.

The vein in the Highland mine contains quartz, commonly with banding or comb structure and vugs. Siderite and green or purple fluorite are present locally. Fine- and coarse-grained galena, sphalerite, and pyrite are the principal sulphides, and chalcopyrite is in minor amounts. Siderite is more abundant on the Buckeye, occurring in the vein and carrying clusters of sulphides where it has replaced the limestone. Lenses of massive sulphides containing pyrrhotite in addition to the other minerals are found in the Libby showings.

HIGHLANDER VEIN SYSTEM

The Highlander vein system in the southern part of the camp near Ainsworth consists of a group of northerly trending veins dipping to the west. The main properties in this system are the Highlander, Banker, and Albion on the Highlander vein, and the Spokane, Maestro, Little Phil, Black Diamond, and Little Donald properties on the Black Diamond-Spokane vein. Nearby properties on the vein system include the Trinket north of the Spokane, the Hector and Danira north of the Highlander vein, and the Little Mamie and Lady of the Lake to the south. The Tariff, an old property on the same vein system, lies to the east. The area including most of these properties was carefully studied by Eastwood in 1951–1953, and the following generalizations are taken from his work.

The Highlander vein outcrops from near Loon Lake to Munn Creek, a distance of about a mile, and the fault zone followed by the vein probably continues both to the south through the lake and to the north through the Hector property. The vein curves from a strike of almost due north near Loon Lake to 20 degrees west of north on the Jack Pot claim north of the Banker. The dip is to the west at about 45 degrees, and although essentially parallel to the formations, it gradually transects them. The wallrocks therefore vary from place to place and are principally fine-grained granites, hornblende schists, and grey mica schists. In addition, two sills of lamprophyre occur within the vein, one of which follows a sheared zone within the vein and is altered and mineralized.

The vein consists of quartz and carbonate mainly a few feet to a few tens of feet thick but locally as much as 150 feet thick. Lenses of sulphides less than 10 feet thick, generally measuring a few hundred feet in length and in depth down the dip, constitute the orebodies. Details of the vein are shown diagrammatically on Figure 21 (Eastwood, 1951, p. 152) and in the descriptions (*see* p. 92). The shape of the orebodies is irregular, and no obvious simple control has been determined. Eastwood suggests that impervious sheets of gouge and altered lamprophyre have affected ore deposition, but he also refers to other unknown factors.

The Spokane-Black Diamond vein includes a fairly continuous narrow quartz vein extending from Munn Creek south to the Black Diamond and at least three short cross-veins intersecting it. Shorter parallel bedded veins occur on the Maestro and Trinket claims. The veins are largely in micaceous quartzite, but a thin layer of hornblende schist is exposed on surface in the footwall of the main Spokane vein. Like the Highlander vein, they curve in strike from about due north at the southern end to north 15 degrees west along most of their length and they dip about 45 degrees to the west. The short cross-veins dip steeply to the south and range in strike from northwest to north 75 degrees west.

Most of the orebodies are irregular without definite rake. Small oreshoots are found where the bedded veins intersect or join the cross-veins. They rake somewhat south of west parallel to the line of intersection of the intersecting veins.

The veins have a simple mineralogy, consisting mainly of quartz with clusters, grains, and irregular masses of galena, sphalerite, pyrite, and minor chalcopyrite. Siderite and calcite are present locally and are abundant where the veins cut limestone.

The Highlander is the widest and structurally most complex of all the veins in the Ainsworth camp. The vein contains early quartz that has been sheared and intruded by lamprophyres and quartz sulphide veins that transect the lamprophyres and cause their alteration. The early quartz is shattered, contains fragments of silicified wallrock, and where seen on surface has irregular boundaries that grade into silicified wallrocks. The quartz sulphide veins tend to have strong walls and to be cavernous with well-formed crystals of quartz and locally of the other minerals.

At places the sulphides, principally galena, are deformed. The relationships in the Highlander vein, which are also seen in the Townsite mine, indicate a sequence of quartz mineralization, lamprophyre dyke intrusion, shearing, and quartz-sulphide mineralization. The later parts of the sequence are seen elsewhere in the camp, but in only the Highlander vein system has the early quartz-lamprophyre association been recognized. Probably some sparsely mineralized quartz veins parallel to the foliation which are found at a number of places throughout the camp also contain early quartz. These include veins in the grey mica schists and hornblende schists on the Skookum and north of the Keystone claims and others on the R.F.G. and north of Lendrum and Woodbury Creeks on the eastern side of the hornblende schists that form the hangingwall of the second fault slice. This early quartz in veins parallel to the foliation is taken to mean that mineralization was initiated during conditions of relative extension across the foliation.

REPLACEMENT DEPOSITS

Two types of lead-zinc replacement deposits are present in the Ainsworth camp. The first is in the Star and No. 1 limestones, and the second is in the Ainsworth limestone and Early Bird Formation north of Cedar Creek.

In the first type of deposit, replacement is associated with, and subordinate to, quartz-carbonate-sulphide mineralization along well-defined faults and fractures. Most of these fractures trend northwest and dip to the south, transgressing and more or less confined to the limestones. Siderite has replaced the limestone near fractures adjacent to the veins and along the contacts of limestone and schist. Pyrite, sphalerite, and galena are disseminated in the siderite, decreasing in amount away from the main fractures or faults. The largest masses of siderite are along the hangingwall of limestone layers and extend a few tens of feet from the main fractures. Lead-zinc mineralization of this sort has been mined in conjunction with mineralization in veins at the Star, Ayesha, Buckeye, and Triumph properties. Silver mineralization at the No. 1 and Silver Hoard properties described by Schofield (1920, pp. 17, 50) as a replacement deposit is associated with carbonates in sheared and crushed zones at or near the western contact of the No. 1 limestone. Sulphides are scarce and there appears to be very little replacement of the wallrocks adjacent to the sheared zones.

Replacement deposits along fractures in the Ainsworth and Early Bird Formations north of Cedar Creek are of particular interest because they resemble the Bluebell deposit (*see* p. 56). On the Lakeshore property, sulphide mineralization is in the lower Ainsworth limestone along fractures which in general strike north 70 to 75 degrees west and dip 60 to 70 degrees to the south. They are tight fractures containing clusters, pods, and grains of galena, sphalerite, pyrite, and pyrrhotite generally without quartz or carbonates. A green manganese-iron silicate, knebelite, generally associated with pyrrhotite, as well as chlorite and iron carbonates are minor alteration products. In drill core and as exposed underground, these minerals are in fractures a few inches thick and extend a few feet into the limestone on each wall of the fracture, gradually decreasing in amount away from the fracture. Analysis of the drill results suggests that replacement has favoured certain layers parallel to the formational attitude of the limestone which include the hangingwall and, to a much smaller extent, the footwall of the limestone. Replacement is not extensive and appears to depend on the number and spacing of the fractures.

Much the same type of mineralization is found in the calcareous parts of the Early Bird Formation near the lower part of Woodbury Creek. Small shipments of replacement ore have been made from fracture zones on Kootenay Lake just north of the mouth of the creek. The deposits discovered so far both in the Early

Bird and Ainsworth limestones have yielded only a few thousand tons of ore, but they constitute the potentially most important type of deposit in the camp. Intensity of fracturing appears to be the most important factor controlling the extent of replacement.

VEIN PATTERN AND HISTORY

The veins in the Ainsworth camp are in a relatively simple set of fractures on which there has been minor faulting. An analysis of mineralized fractures shows that there are three dominant attitudes for the veins, as follows:—

(1) Bedded veins striking between north and north 20 degrees west and dipping 45 degrees west.
(2) Veins striking northwest and dipping 60 degrees southwest.
(3) Veins striking between west and north 70 degrees west and dipping 55 degrees to the south.

These orientations are clearly defined in many of the main ore zones and are perpetuated in the minor deposits and in relatively insignificant mineralized fractures. They are not defined, however, by unmineralized fractures measured at random. An analysis of all fractures between Cedar and Coffee Creeks failed to show any preferred orientations, but an analysis of mineralized fractures throughout the camp gave the results indicated above and shown diagrammatically on Figure 8. The mineralized fractures used in the analysis included any fracture or fault containing quartz, carbonates, fluorite, or sulphides.

Veins essentially parallel to the foliation, called bedded veins, are the dominant type south of Cedar Creek. In the Highlander system three veins more or less continuous over a strike length of up to a mile are essentially parallel to the foliation. Because of the lenticular character of the wallrocks due to granitic intrusion and old folds and faults, the bedded veins tend to pass from one rock type to another. They are zones of repeated fracturing, faulting, and mineralization, and they contain lamprophyre sills. Many bedded veins are found south and west of the Highlander system, the most important of which are on the Krao, Crow Fledgling, and Eden and Crescent properties.

Bedded veins are rarely found north of Cedar Creek, but they do occur as branches or splits from transgressive veins. On the Libby at the southeastern end of the Highland system, several veins in going south swing from a southeasterly strike into the foliation. Similarly at the northwest end of the Highland system, the main Highland vein passes northwest into the foliation.

Veins trending between west and northwest and dipping at moderate to steep angles to the south are dominant north of Cedar Creek. Veins trending northwest and west-northwest occur together, though each system has its own characteristics. The dominant strike of the Highland system, for example, is northwest and the dip is 65 to 75 degrees to the southwest, but subsidiary veins strike north 80 degrees west and dip 70 degrees south. The main Florence vein strikes north 75 degrees west and dips 45 degrees to the south, but many veins strike more nearly east-west and dip more steeply to the south.

Northwesterly trending veins form a minor but significant part of the vein systems south of Cedar Creek. The United vein system contains several northwesterly trending veins, and the Highlander system, though dominantly bedded, has several small northwesterly trending parts, the most important of which are on the Black Diamond claim (*see* Fig. 19).

This statistical analysis of the attitudes of the mineralized fractures indicates only the dominant trends. Of greater significance in mining and exploration are the patterns of individual veins, many of which are shown in the maps and sketches of Chapter IV.

The vein fractures have been the locus of small and repeated movements. Offset of the formations by the vein fractures has been noted at many of the mines, though the actual displacement has not been determined at any of them. The offsets are almost entirely to the left, and the largest, about 200 feet, is on the Florence vein system. Slickensides present on many of the fault planes plunge steeply, and it is clear that the veins follow normal faults in which the south side has dropped in relation to the north. The offset varies from place to place along individual veins and vein systems because the veins branch and the movement is taken up on subsidiary veins or on the foliation.

The bedded veins also are loci of repeated faulting and fracturing, but it is difficult to determine the amount and direction of movement. Slickensides on the hangingwall of several bedded veins plunge down the dip, suggesting late dip-slip movements. It is significant that the veins of the Highlander system, the largest and most continuous of the bedded veins, are in a part of the area in which the regional strike is abnormal. The formations and the veins in the Highlander system swing from due north near the southern end of the system to strike north 20 degrees west where the veins are thickest and most continuous. To provide openings on such fractures, facilitating mineralization, a tendency for strike slip on the foliation planes with the east side moving northward in relation to the west is required. It is suggested that strike slip of this sort was dominant in the early history of faulting and may have initiated the entire fracture system.

A detailed history of the mineralization is difficult to determine, and only a few of the more general characteristics are known. The fracture system which was subsequently mineralized clearly developed in brittle rocks after a long and complex history of plastic deformation, metamorphism, and granitic intrusion. As suggested above, the fracture system may have been initiated by a stress system that tended to produce a left-hand strike slip on the foliation planes. Greyish crushed quartz associated with silicified wallrocks found in the Highlander vein (*see* p. 48) forms the earliest known mineralization. The intrusion of lamprophyre dykes followed this mineralization and probably was accompanied or followed by changing stress which permitted normal faulting. Faulting and quartz-carbonate-sulphide mineralization continued together and followed the emplacement of the lamprophyres. Details of the mineralization probably vary from one deposit to another and have produced the individual characteristics of the deposits.

ORESHOOTS

Sulphide mineralization is found in special sites within the veins. The orebodies are relatively small, and to be economic the search for them must be efficient and can permit only a limited amount of diamond drilling and exploratory driving. In the past the success of a mine has depended on the operators recognizing the special sites of sulphide mineralization and following the ore. Old-time miners and lessees mined the orebodies as efficiently as they could, probably without much appreciation for ore controls. Some of these controls after extensive mining are now clear, but some are not so clear, and there is still a place in the camp for the miner with a " nose for ore."

Controls of mineralization are most easily recognized in the transverse veins. Sulphides tend to be concentrated in them where (*a*) they pass from one rock type to another, (*b*) where they branch or split either along strike or up the dip, and (*c*) where they tend to open by faulting on the vein. Commonly these situations are combined, as is indicated by the following examples.

Many oreshoots are found where veins pass from schist to limestone. The best examples are in the Star limestone on the Buckeye property (*see* p. 75), in which the Buckeye and almost a dozen small veins north of it contain pods of sulphides where the veins pass from grey knotted schist into fine-grained grey limestone. On the Buckeye the sulphides have spread out along the hangingwall of the limestone for 10 to 20 feet from the vein. The vein fault continues through the limestone into schists, and siderite and sulphides have replaced the limestone. In the Highland mine the ore is mainly in hornblende schist near a contact with micaceous quartzite lying beneath and east of the schist. The orebodies along three principal veins gradually pinch out a few hundred feet into the hornblende schist from the schist-quartzite contact and extend less than 100 feet into the quartzite. On the Crow Fledgling, the principal vein strikes northwest crossing the hangingwall of the Krao limestone where it splits. One branch continues northwest into quartzites and is not mineralized; the other follows the hangingwall of the limestone for a few hundred feet before resuming a northwesterly strike. The thickest and highest-grade sulphides are at the two points where the vein curves from a northwest strike to a northerly strike along the hangingwall of the limestone.

In general, transverse veins dipping to the southwest intersect the formations, which dip to the west less steeply than the veins, along a line plunging somewhat south of west, and this intersection is parallel to the plunge or rake of the oreshoots.

In the foregoing situation, ore appears to be associated with a favourable rock type. Limestone is clearly the most favourable rock in the camp, and at the Highland as well as elsewhere hornblende schist is a favourable rock. The situations described are the result of the structure and contrasting strengths of the wallrocks, and the chemical nature of the wallrocks is probably a subsidiary factor affecting sulphide deposition.

In the Kootenay Florence mine the principal ore zones are found where the vein splits in passing through the upper and lower Ainsworth limestones. Two zones have been mined up the dip of the vein for several hundred feet. Judging from level plans, the veins also split in the vertical direction, and it appears that the split sections, which contain a number of closely spaced veins, are caused by movement on the vein fracture. The vein on parts of four levels of the mine is shown diagrammatically on Figure 23, from which it is clear that left-hand offset of the walls of the vein would cause tension on the short easterly striking veins in the split sections. In cross-section the footwall strands of the veins have the lowest dip, and the steeper strands that break into the hangingwall are, as the hangingwall moves downward, also in tension. Although the position of the splits is probably controlled by the rock type through which the vein passes, the split sections do not follow the formations up or down the dip. In general, the rake of the two ore zones in the Kootenay Florence is steeper than the dip of the layers.

In the bedded veins the control of sulphide mineralization is more difficult to determine. In general, sulphide deposition depended on reopening of the veins by repeated movements within or adjacent to the early barren quartz veins. These movements produced shears and crushed zones which permitted the migration of solutions. In the Highlander vein, Eastwood states that " ore deposition is believed to have been partly localized by the relatively impervious sheets of gouge and altered lamprophyre, but further localization by some unknown factor separated the ore zone into alternations of orebodies and barren stretches. These orebodies rake north and are tabular, with relatively blunt north and gently tapering south edges. Four are indicated within the area. Within the orebodies, ore normally occurs between the shear and lamprophyre where they are close together and tails out where they diverge. The tails follow either wall of either shear or lamprophyre and also follow some subsidiary shears between the sheets. Ore more than 3 inches thick rarely occurs in the shear wall away from the lamprophyre and nowhere in the lamprophyre wall away from the shear."

Orebodies on the Spokane vein are extremely irregular and no pattern of mineralization is recognized. Locally sulphides occur as small steeply plunging lenses where transverse veins intersect the bedded Spokane vein. An orebody on the Black Diamond is the most significant of this sort.

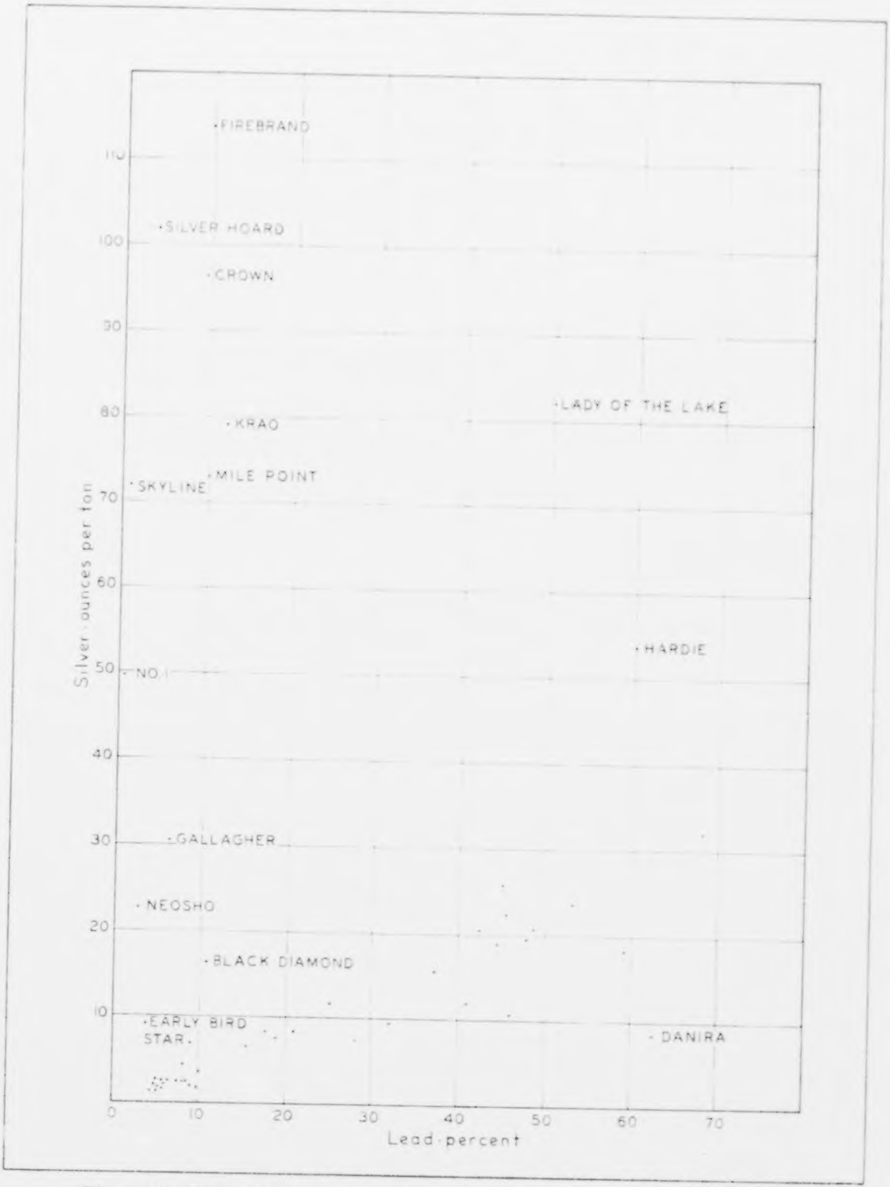


Figure 11. Graph showing the grades in silver and lead in the Ainsworth camp.

SIZE AND GRADE OF OREBODIES

Individual orebodies in the Ainsworth camp are small. Mostly they are tabular and lenticular, ranging from a few inches to a few feet thick and measuring no more than a few hundred feet along strike and down dip. In the larger mines it is difficult to obtain data on the sizes of individual orebodies. The largest stoped areas in the Highlander mine extend about 600 feet along the strike and 800 feet parallel to the dip. Published reports indicate that sulphides mined were commonly 4 to 6 feet and locally as much as 10 feet thick. In the Kootenay Florence, orebodies are reported to have been up to 15 feet thick, and stoped areas measure 200 to 400 feet in the strike and dip direction, but from the work done it is not possible to be certain of the full extent of the orebodies. On many properties only one orebody has been mined. Most of these are less than 5 feet thick, extend a few tens of feet along the strike, and have been mined to depths of less than 100 feet.

In the present study it has not been possible to obtain estimates of the grade of the veins through sampling. Estimates of grades can be obtained from production statistics (*see* Table 1, p. 44), but these are affected strongly by mining and milling practice, and by the fact that some of the statistics are incomplete. Much of the shipping ore was sorted to increase the grade in silver. Zinc was not produced for many years, so that average figures do not give a true indication of the grade in zinc. From production figures, however, it is clear that grades of more than 50 per cent lead and 20 per cent zinc were obtained in ore sorted for direct shipping, whereas grades of about 5 per cent lead and 2 per cent zinc were commonly obtained in ore mined in quantity for milling. Grades in silver and lead based on total production from individual properties are shown on Figure 11. The graph shows that in general in most ores the silver varies with the lead and amounts to one-half to one-third of an ounce per ton for every unit of lead. Spectacularly high grades in silver of more than 100 ounces per ton were obtained (*see* Schofield) in several small shipments, many of them from surface or shallow workings in the early days of production. A shipment from the Crown claim in 1963 which averaged 96 ounces per ton silver was an earthy gossan obtained from surface workings. Production of apparently unoxidized consistently high-grade silver ore has come from the Krao, Black Diamond, No. 1, and Silver Hoard mines from relatively shallow workings.

MINERALOGY

The principal sulphides are pyrite, galena, sphalerite, chalcopyrite, and pyrrhotite. Arsenopyrite has been noted in a few places. Galena is usually massive and medium grained but locally has a gneissic structure or is very fine-grained " steel galena." Galena crystals have been reported from some of the mines, and in 1963 several vugs with intergrown galena crystals up to 1½ inches wide were taken from the Krao mine. Sphalerite is resinous brown, locally occurring as well-formed crystals, some of the most spectacular of which came from a hot-water cave in the Kootenay Florence mine. Small amounts of chalcopyrite are present in essentially all the mines either as discrete grains or intimately associated with sphalerite.

Pyrrhotite occurs in the northern part of the camp but not in the south. It is present in the New Jerusalem just south of Cedar Creek and in the Libby just north of the creek but has not been found in any of the veins south of these properties and is present in many places to the north. Commonly pyrrhotite is rimmed or replaced along fractures by pyrite. Pyrite occurs by itself as well-formed crystals or clusters of grains, but where it replaces pyrrhotite it commonly has a colloform porous texture. A study of polished sections shows more than one age of pyrrhotite and suggests that pyrrhotite is more widespread than indicated in the field.

Wire silver is the only silver mineral recognized in the camp. It has been reported from the Krao, Skyline, No. 1, Silver Hoard, and Gallagher properties and probably was present in many of the workings from which the early high silver shipments were made. Most of these workings are shallow.

The main gangue minerals are quartz, calcite, siderite, and fluorite. Quartz is abundant in all the principal vein systems. Carbonates, particularly siderite, are most common in veins associated with the Star and No. 1 limestones. Siderite occurs within the vein and as a replacement of the limestones adjacent to veins and subsidiary fractures. Other iron carbonates and probably manganiferous iron carbonates are also present, but these have not been positively identified. Fluorite is present mainly as linings of cavities or fillings of vugs and appears to have been deposited late in the mineralization sequence.

Wallrocks adjacent to veins and fractures have been altered to contain chlorite, sericite, carbonates, and a manganese-bearing mineral of the olivine group called knebelite. Alternation extends only a foot or so from the veins and fractures. Sericite causes a bleached zone. Siderite, common in deposits in the Star and No. 1 limestones, is found also in the hornblende schists and causes rusty zones where weathered. Knebelite is found with deposits in the Ainsworth limestone and Early Bird Formation north of Cedar Creek. Knebelite has been positively identified only at the Lakeshore property, but chlorite and rusty-weathering carbonates probably resulting from the alteration of knebelite are found at the Nicolet and Bell properties and in some deposits on lower Woodbury Creek. Knebelite is commonly associated with lead-zinc mineralization at the Bluebell mine, and its discovery in the Ainsworth camp by geologists of Cominco Ltd. has been taken to indicate a genetic relationship between the Bluebell and Lakeshore properties.

HOT SPRINGS AND OXIDATION

Hot waters issuing from springs or encountered in drilling and mining are present in several localities in the Ainsworth camp. The hot springs in the Ainsworth townsite, which attracted early settlers for many years, have been impounded and used for bathing. " Mineral springs " are reported to occur on Woodbury Creek flowing from a zone of intense shearing called the Woodbury " soft lead." To the south, surface diamond drilling by Cominco near the No. 1 level of the Kootenay Florence mine encountered very high gas pressures in a zone that probably joins the Woodbury " soft lead." A cave containing hot water was encountered in 1928 in driving crosscuts on No. 9 level of the Kootenay Florence mine. Although temperatures have not been recorded, the cave is too hot to be entered comfortably. It was originally lined with exceptionally fine crystals of fluorite, but these have been removed.

Water temperatures and analyses have been made from the underground workings of the Bluebell mine. In 1962 a flow of water and carbon dioxide from a drill-hole at 400 imperial gallons per minute and a pressure of 325 pounds per square inch was at a temperature of 105 degrees Fahrenheit. Analyses of mine waters supplied by Cominco are shown in Table 2. The water in the mine is a mixture of " thermal " water, regarded as coming from depth, and surface water. It is difficult to distinguish one from the other and not possible to be certain that any sample is not a mixture. Analyses show, however, that thermal waters are abnormally high in chlorine, which may amount to as much as 150 parts per million.

Orebodies in the Ainsworth camp are oxidized in general for only a few feet below the surface. Earthy gossans at several of the properties in the Star and No. 1 limestones, particularly at the Gallagher, Crown, and Skyline, have yielded excep-

TABLE 2.—ANALYSES OF MINE WATERS FROM THE BLUEBELL MINE

Source	Parts per Million											pH	Temp.
	Total Dissolved Solids	Ca	Mg	Na	SiO_2	Fe	HCO_3	SO_4	Cl	F	SO_2		
3 level thermal	3,300	430	280	440	—	1	1,700	280	80	2	110	6.4	80° F.
8 level thermal	2.120	530	302	N.D.	—	12	N.D.	84	58	N.D.	55	6.3	66° F.
Cool water—3 level	300	71	14	11	—	0.1	100	66	1	1.5	14	7.0	40° F.
No. 1 shaft	2,500	410	160	290	60	N.D.	N.D.	190	50	N.D.	N.D.	6.6	70° F.

NOTE.—" N.D." means not determined.

tionally high grades in silver. Only minor amounts of oxidized ore have been encountered in the deeper underground workings, but Hedley describes oxidation going on at the present time in the Kootenay Florence mine near the hot-water cave. " Mining is made difficult by bad air and bad ground. The air in unventilated workings is deficient in oxygen, a result apparently of strong oxidation. In 1951 none of the workings west of the east ore zone could be entered and the raise to No. 5 level had caved completely cutting off natural ventilation (*see* Fig. 23). The bad ground is a result of slaking and swelling of some limestone and limy schist, a condition exaggerated by dampness. The final product is a sort of plastic mud in which it is very difficult to maintain openings " (*see* Hedley, 1951).

Oxidation in the Bluebell and Comfort zones of the Bluebell mine is extensive to depths as great as 350 feet below the level of Kootenay Lake. It results in a reddish-brown gossan composed mainly of limonite with minor amounts of pyrite and secondary lead and zinc minerals. Coatings of a red oxide are fairly common. In contrast to mines in the Ainsworth camp, the grade of oxidized parts of the Bluebell and Comfort orebodies is low and mining of the oxidized zone is carried on only where there are significant unoxidized remnants of sulphide ore.

COMPARISON OF MINES OF THE AINSWORTH CAMP AND THE BLUEBELL MINE

The discovery of a mine in the Ainsworth camp of the size and grade of the Bluebell has been the hope of prospecting and exploration programmes from the earliest days. The latest attempt between 1952 and 1957 on the Nicolet, Carey, and Snelling claims by Cominco Ltd., based on extensive experience at the Bluebell and up-to-date exploration methods, through encouraging, was not successful. This exploration showed that geological conditions almost identical with those at the Bluebell are present in the northern part of the Ainsworth camp, but orebodies of the size and grade of the Bluebell have not yet been discovered. The following notes, based on published descriptions of the Bluebell (*see* Irvine, 1957, and Can. Min. Jour., 1954), brief visits to the mine and regional reconnaissance, point up the similarities and some of the contrasts between the Bluebell and the northern part of the Ainsworth camp.

The Bluebell orebodies are more or less massive replacements of limestone controlled by cross-fractures. The limestone, called the Bluebell limestone, is 100 to 150 feet thick and dips on the average 35 degrees to the west. Immediately to the west in the hangingwall is a layer up to 60 feet thick of mica schist and micaceous quartzite with calcareous lenses and one prominent layer of limestone up to 15 feet thick. Farther west is a thick sequence of white and greyish-brown micaceous quartzites. To the east, in the footwall of the limestone, the rocks are calcareous lime silicate gneisses, and hornblende gneisses with thin layers of grey or brown mica schist adjacent to the limestone.

The Bluebell limestone is correlated with the Badshot Formation (*see* p. 61), the hangingwall micaceous rocks, and the thin limestone with the Mohican, and the quartzites with the upper part of the Hamill Group. The footwall rocks are in the lower part of the Lardeau Group. The sequence is so similar to that found in the western part of the Duncan Lake area (*see* Fyles, 1964, p. 32) that there seems to be little doubt in this correlation. It indicates that the rocks at the Bluebell are overturned.

Lenticular sheets of granite and pegmatite up to several feet thick and lying parallel to the foliation are important in the mine. Also dark-green dykes, many of which are like the lamprophyres of the Ainsworth camp (*see* p. 41), transect the formations.

The structure along the eastern side of Kootenay Lake near the Bluebell mine appears to be simple. The layers dip uniformly to the west at low to moderate angles. The strike swings from north 15 degrees west, south of the mine, through north, to north 15 degrees east north of the mine, and, on a smaller scale, prominent concentric warps of the foliation, measured in tens of feet, plunge to the southwest. Strong lineations that are folded by these warps are parallel to the axes of isoclinal folds plunging at low angles to the north. These folds are well displayed in quartzites on the shore west of the mine and underground. They are part of a series of folds which on a regional scale cause complicated repetitions of the formations, the pattern of which has been determined at the north end of Kootenay Lake (*see* p. 62 and Fyles, 1964, p. 61). These structures are of little significance within the mine area, except that locally minor folds have extended and controlled sulphide replacement.

The ore zones at the Bluebell mine are the Comfort and Bluebell in the north and the Kootenay Chief in the south. They are associated with cross-joints having the following attitudes (Irvine, 1957, p. 102):—

Comfort: North 72 degrees west at 83 degrees north.
Bluebell: North 75½ degrees west at 82 degrees south.
Kootenay Chief: North 62½ degrees west at 84½ degrees north.

These joints are part of a regional set. Figure 8 summarizes the attitude of 82 mineralized joints, faults, and lamprophyre dykes on the eastern shore of the lake from 2 miles north to 2 miles south of the Bluebell mine. Although the principal mineralization is at the Bluebell mine, small veins in the footwall rocks have been explored, and many joints contain quartz or carbonates or show narrow marginal zones of alteration. In addition, some contain lamprophyre dykes which are older than the sulphide mineralization. Although the origin of the joint set is uncertain, it is clear that it has developed over an extended period of time. It is subsequent to the isoclinal folding and developed while the rocks had their present general attitude. Gentle cross-warping, strike slip parallel to the foliation, and normal fault movements are suggested as possible causes. Various sorts of mineralization and lamprophyre dyke intrusion accompanied the joint formation and development.

The orebodies at the Bluebell mine are described by Irvine (1957) as follows:—

" There are three known centres of mineralization in the mine, spaced at approximately 1,500-foot intervals along the strike of the Bluebell limestone. In these mineralized centres the lead-zinc orebodies, which occur as heavy sulphide replacements, are localized along steep cross-fractures, which extend across the limestone from hanging-wall to footwall. The cross-fractures themselves are only a portion of an inch in width, the ore shoots being formed by sulphide replacements along beds adjoining the fractures. Replacement of this sort proceeds in irregular fashion for

5 to 10 feet from the fractures, then cuts out abruptly. The shoots thus form tabular bodies, transverse to the bedding and having irregular outlines due to variations in the extent to which replacement has proceeded along various beds cut by the cross-fractures. In places the control of the mineralization will shift from one cross-fracture to an adjoining one, or there may be several adjoining cross-fractures, each with sulphide mineralization. Where mineralized fractures are closely bunched in this way the ore may coalesce into larger bodies, 30 to 40 feet, or in exceptional cases as much as 100 feet, in width. Where beds particularly favourable to sulphide deposition occur, the ore may spread out from the mineralized fractures for as much as 100 feet along bedding planes. The most consistently favourable beds for replacement of this type are the dense, closely banded limestone beds in the upper part of the Bluebell limestone, and the ore occurs either just under the hanging-wall quartzite or just under the pegmatite sills which lie a few feet stratigraphically below the base of the quartzite.

" In the Comfort ore zone, at the north end of the mine, there are at least five known orebodies, all more or less tabular, occupying transverse fracture zones and raking steeply down the dip of the beds. These occur along a strike length of 1,200 feet, and are separated by completely barren limestone. In general the Comfort orebodies follow only cross-fractures, but the principal and central body of the group, which is known to be continuous for at least 600 feet down dip from surface, spreads out along beds under the hanging-wall quartzite and again under a pegmatite sill just below the quartzite. As it follows cross-fractures toward the stratigraphically central portion of the limestone, the orebody narrows and almost pinches out, then spreads to a greater width as it approaches the footwall of the limestone formation. The north boundary of this orebody is here marked by a steeply dipping green dyke, transverse to the bedding in strike.

" The Bluebell ore zone, from which all the ore was mined prior to Cominco acquiring the property, lies south of the Comfort zone, and is separated from it along the strike of the limestone formation by a 1,000-foot barren interval. Three ore shoots occur as stubby keels, clustered close to the hanging-wall of the limestone and occupying a strike length of 400 feet. The ore has been mined 800 feet down dip from the surface, and may go deeper. In the central portion of the zone, the ore follows limestone beds just below the hanging-wall quartzite, and in the main it follows cross-fractures for only a small stratigraphic distance below the hanging-wall. In this respect, the Bluebell ore zone differs from the other ore zones in the mine, where the ore following cross-fractures goes much deeper into the limestone formation.

" The Kootenay Chief ore zone, from which most of the recent production has come, is south of the Bluebell zone, and is separated from it by about 900 feet of barren limestone. Orebodies in this zone are known to occur along a strike length of 1,200 feet in the limestone formation, and have been traced for at least 1,200 feet down dip from the surface. Five principal orebodies have been identified, and the general pattern is one of ore spreading out along beds near the hanging-wall of the limestone from mineralized cross-fractures which may penetrate as deep as the footwall. The bedding-type ore shoots have somewhat irregular shapes when viewed in the plane of the bedding, but follow the rake of the cross-fractures faithfully down the dip of the beds. One large orebody near the central portion of the ore zone is composed of a number of closely spaced mineralized cross-fractures extending from footwall to hanging-wall of the limestone. This body has swelled out in places to a width of 100 feet, and is the largest and most continuous so far encountered in the mine.

"The chief sulphide minerals found in the orebodies are pyrrhotite, marmatitic sphalerite, and galena, in that order of abundance. Pyrite, chalcopyrite, and arsenopyrite are persistent, but minor sulphide minerals and scattered amounts of light-coloured sphalerite are found filling late fractures. Quartz is a common gangue mineral, being found associated with the sulphides in most places. Knebelite, a manganiferous orthosilicate closely related to fayalite, is found in limited amounts in or near most of the orebodies."

A close geological parallel can be drawn between the Bluebell mine area and the northern part of the Ainsworth camp. The Lakeshore property in particular closely resembles the Bluebell mine, and this similarity led to the recent exploration of the Lakeshore by Cominco Ltd.

Though part of the regional fracture system, the Lakeshore and nearby fractures in the lower Ainsworth limestone and the main fracture in the Bluebell have attitudes that contrast with those of the regional set. The Bluebell and Lakeshore fractures have the same strike, but a somewhat different dip. They contrast with other fractures both in the Ainsworth camp and on the eastern shore of Kootenay Lake (*see* Fig. 8). The fracture pattern has developed over an extended period of time, as indicated by fault movements, mineralization, and intrusion (*see* p. 51), and it is suggested that the Lakeshore and Bluebell fractures represent one phase in the development of the fracture system. Spacing of the fractures seems to be one of the main controls of replacement and one of the main differences between the Bluebell and the Lakeshore. Probably the mechanical properties of the individual rock units and of the lithological succession resulted in more closely spaced fractures at the Bluebell. The strong quartzite hangingwall and the clean Bluebell limestone may have been the main causes of the intense fracturing that made sulphide replacement more widespread and more intense at the Bluebell than it appears to have been in the northern part of the Ainsworth camp.

Among the minerals present in the Bluebell and Lakeshore deposits, knebelite and pyrrhotite are probably the most significant. Knebelite has a limited distribution in the Ainsworth camp (*see* p. 55) and serves to point up the close relationship between the Bluebell and Lakeshore. Studies at the Bluebell indicate that knebelite was one of the earliest minerals to be deposited. It is partly replaced by pyrrhotite and associated with quartz. Very minor amounts of pyrite closely associated with pyrrhotite are found at the Bluebell, principally in the Kootenay Chief zone. Pyrrhotite replaced by pyrite is common in the northern part of the Ainsworth camp (*see* p. 54). Although geochemical estimates of the temperatures of deposition have not been made, it is suggested that knebelite, pyrrhotite, and pyrite represent stages in the mineralization process controlled by decreasing temperatures of deposition. It may be that the Lakeshore and Bluebell fractures received a relatively early high temperature phase of sulphide mineralization that subsequently spread to other fractures at somewhat lower temperatures.

CHAPTER IV.—STRUCTURE AND LEAD-ZINC MINERALIZATION IN THE KOOTENAY ARC

INTRODUCTION

The Ainsworth camp in the central part of the Kootenay arc (*see* p. 9) is one of a number of areas of lead-zinc mineralization extending from the Metaline and Leadpoint districts of Northeastern Washington into the Shuswap metamorphic complex beyond the arc. The deposits in Washington are followed to the north by those in the Salmo area. Farther north is the Ainsworth camp and to the west, mainly between the Nelson and Kuskanax batholiths, is the Slocan camp. The Lardeau district from the north end of Kootenay Lake to the Columbia River near Revelstoke contains a variety of lead-zinc deposits, mainly in two groups—one in the south Lardeau around Duncan Lake and the other in the central Lardeau around Ferguson and Camborne. These main centres of mineralization are shown on Figure 12 (in pocket).

Studies of lead-zinc mineralization in the Kootenay arc have been made by the British Columbia Department of Mines and Petroleum Resources for more than 20 years, beginning with the work of Hedley (1947 and 1952) in the Retallack and Sandon areas and continuing with studies in the Salmo, central Lardeau, Duncan Lake, and Ainsworth areas (*see* Fyles and Hewlett, 1959; Fyles and Eastwood, 1962; and Fyles, 1964). These have been studies of the geological setting of the mineral deposits and have emphasized the stratigraphy and structure of the enclosing rocks and their relationships to the form of the orebodies. These studies have provided a background both for exploration and for further scientific work.

One important result of the studies of the geological setting of the deposits has been an understanding of the structure of the various mining camps. In general, only structural reconnaissance between the camps has been done by the Department of Mines and Petroleum Resources, but regional maps of the Geological Survey of Canada link the formations from one camp to the next. In the areas that have been studied in detail, patterns of folding are recognized that can at least tentatively be correlated throughout the arc. A preliminary account of the dominant phases of deformation has already been given (*see* Fyles, 1962), but it has been modified by more recent work. Continuing structural studies by the Geological Survey of Canada and the University of British Columbia will undoubtedly lead to a better understanding of the structure.

This bulletin on the Ainsworth camp concludes more than 20 years of work on the geological setting of lead-zinc deposits in the arc. In spite of the fact that studies by others are continuing, it is felt that a summary of the present knowledge of the regional structure of the arc and of the main characteristics of the lead-zinc mineralization should be made. These topics together with some of the outstanding geological problems are discussed in this chapter. The structural problems involve correlations both within the arc and beyond it to the adjacent areas of the Purcell anticlinorium, the Shuswap terrane, and the northern Selkirk Mountains. The problems of lead-zinc mineralization in their most general form include the age of mineralization, the physical-chemical conditions at the time of deposition, and the immediate source and the history of the sulphides. Research is continuing in the expectation that answers to these problems will aid in the discovery of new deposits and in finding extensions of known ones.

REGIONAL STRUCTURE

Deformation in the Kootenay arc has taken place over an extended period of time. Little is known of the absolute age of deformation or the length of time over which deformation took place. Field work reveals parts of a sequence of folding which are thought of as related phases of one long continuous process. The most important folds belong to the two oldest known phases of deformation and are called Phase I and Phase II folds. Other folds belonging to later phases of folding are known, but they are thought to be of local origin or subordinate in the regional picture. In general, Phase I and Phase II folds have essentially parallel axes with a low plunge. South of the West Arm of Kootenay Lake the plunge is to the south, and along northern Kootenay Lake and through most of the Lardeau it is to the north and northwest. The low plunge of both Phase I and Phase II folds produce outcrop patterns with relatively great continuity along strike. It also permits the structure to be accurately depicted by vertical cross-sections. Figure 12 is a generalized map of the Kootenay arc with four composite cross-sections.

The Kootenay arc contains a thick succession of sedimentary and volcanic rocks ranging in age from earliest Cambrian to late Mesozoic. The succession is essentially a conformable one, though a late Palæozoic and an early Mesozoic disconformity are thought to be present (*see* Cairnes, 1934, p. 58) and probably others exist which have not yet been found. One of the most significant markers in the succession is the Badshot limestone in the Lardeau and Kootenay Lake country and the equivalent Reeves limestone south of Nelson near Salmo. These limestones, which contain rare Lower Cambrian Archæocyathids, are repeated by complex folding and are exposed in a belt, locally as much as 10 miles wide, along the eastern side of the arc. Rocks to the east of this belt in general are older than the limestone and pass downward into the Precambrian. Younger rocks to the west comprise a thick succession extending into the Jurassic.

In the Lardeau and Kootenay Lake areas the rocks belong to the Hamill, Lardeau, Milford, Kaslo, and Slocan Groups. The Hamill is quartzitic; the Lardeau has a lower calcareous section containing the Badshot limestone, overlain by a thick succession of schists and quartzites with lenticular masses of volcanic rock. One of the most distinctive markers in the schist-quartzite succession is a grey massive quartzite known as the Ajax. In the Salmo district the lower part of the succession is very similar lithologically to that in the Lardeau district. The lowest group (Quartzite Range and Reno Formations) is quartzitic, and the overlying Laib has a lower calcareous part containing the Reeves limestone, beneath a thick succession of schists and minor quartzites. The overlying Nelway, which is Cambrian limestone and dolomite, and the Active Formation of Ordovician dark slate and argillite occur widely, especially in Washington, but are not found far north of the latitude of Ymir. The Milford, Kaslo, and parts of the Slocan are described in Chapter II, and lithologically similar rocks are found in the southern part of the arc (*see* Little, 1960). A discussion of stratigraphic correlations within the arc has been given in Bulletin No. 49 (Fyles, 1964, pp. 32–36).

The relationships between the two phases of folding are most clearly displayed in the Duncan Lake area, and for this reason are discussed first. The same pattern of folding extends southward along Kootenay Lake and is recognized again in the Salmo district, and these areas are described subsequently. In the area northwest of Duncan Lake, which is described last, Phase I folds are not well known and Phase II folds are the dominant structures.

STRUCTURE OF THE SOUTH LARDEAU AND KOOTENAY LAKE DISTRICT

In the southern part of the Lardeau district around Duncan Lake and the north end of Kootenay Lake, Phase I folds are isoclinal and extremely attenuated. In general, convergence of the limbs cannot be measured in the field and the fold hinges cannot be seen. The folds are recognized from a knowledge of stratigraphic relationships and map patterns of rock units. These folds plunge to the north at about 10 degrees. Their limbs and axial planes are curved and have been folded on Phase II structures.

The axes of Phase II folds plunge at about the same angle to the north as the Phase I folds. Phase II folds range in shape from very tight to relatively open, and in size from a few feet across to folds with axial planes several miles apart. They can be seen in the field and in general are outlined by the layering and by the attitudes of formational contacts. Ideally complete Phase II folds are composed of an anticline lying east of a complementary syncline, giving the form of a reversed letter N (И) . The axial planes of Phase II folds change systematically from a low to moderate westerly dip along Kootenay Lake through a steep westerly dip at the north end of the lake to a vertical or northeasterly dip west of Duncan Lake. The change in dip is accompanied by a swing in the strike of the axial planes from north along Kootenay Lake to northwest west of Duncan Lake.

Figure 12, section B-B′, is an idealized composite section showing the structure at the north end of Kootenay Lake. Both Phase I and Phase II folds are shown and are described in detail in Bulletin No. 49. They have been traced throughout the Duncan Lake area a distance along strike of about 25 miles, in which distance, because of the uniform plunge, a structural depth of more than 3 miles is implied.

South of the north end of Kootenay Lake folds near the hinge zone or beneath the Meadow Creek anticline are found along the west side of the lake, extending into the first fault slice of the Ainsworth-Kaslo area. Section C-C′ is an idealized section between Fletcher and Bjerkness Creeks, extended hypothetically eastward into the lake to include the Badshot and Hamill rocks exposed north of Kaslo and at Riondel. Although correlations of the structure from one fault slice to the next cannot be made with certainty, tentative correlations have been made as outlined in Chapter II. Isoclinal folds with curving axial planes are regarded as Phase I structures—more open folds with reversed N shape when viewed from the south and with axial planes dipping westward at low to moderate angles are regarded as Phase II folds. The isoclinal folds in the second fault slice such as the Krao anticline (*see* p. 28) are considered to be Phase I structures.

Extrapolation of the structures beyond the areas of Duncan Lake and northern part of Kootenay Lake is speculative, because the structures can be followed only by detailed mapping. The Slocan fold of the Sandon area 15 miles west of Kaslo and north of the Nelson batholith resembles a Phase II fold. Parasitic folds on the overturned limb of the Slocan fold have essentially horizontal axial planes and northwesterly trending axes (*see* Hedley, 1947, p. 32). In form they closely resemble folds on the north side of Bjerkness Creek (*see* Plate XIII), which are correlated with Phase II structures. Phase I structures have not been recognized in the Sandon area. Structural studies begun in 1966 by the University of British Columbia are continuing and may clarify these relationships. Speculative correlations of structures in the Salmo and central Lardeau districts with those in the Duncan Lake and Ainsworth-Kaslo areas are made on the basis of reconnaissance which has been done south of the Ainsworth area and northwest of the Duncan Lake area.

STRUCTURE IN THE SALMO AREA

South of the West Arm of Kootenay Lake the regional west-dipping foliation gradually steepens. North of the latitude of Ymir it is essentially vertical, and from there southward it dips steeply to the east. All this region is complicated by faults and granitic intrusions, and in the Salmo area by an abrupt swing in the regional strike. Section D-D′, Figure 12, is across a part of the Salmo area in which the regional strike is north and the plunge of the folds is low, dominantly to the south.

On the eastern edge of the section, the Reeves limestone is repeated on the limbs of an isoclinal syncline, the Laib syncline, west of which is a complementary anticline known as the Sheep Creek anticline. These are Phase I folds, and are typical of structures in the Eastern belt of the Salmo district. They are followed to the west by a complex deep syncline called the Black Argillite belt containing incompetent rocks of the Ordovician Active Formation. West of the Black Argillite belt, rocks lying between the uppermost members of the Quartzite Range Formation and the top of the Laib Formation are complexly folded. They are in the Mine belt and in broadest structural form are anticlinal. The Mine belt and the synclinal Black Argillite belt form a pair of Phase I folds, comparable to the Duncan anticline and Howser syncline of the Duncan Lake area.

Phase II folds are most obvious in the Mine belt, and Phase I folds are relatively obscure. They are defined by the attitudes of foliation planes and range from tight to relatively open. Probably the best-known Phase II folds are in the Jersey mine, where the axial planes dip steeply to the east and the axes plunge southward with the plunge of the Phase I folds. Relatively obscure Phase II folds in the Black Argillite and Eastern belts cause folding of the axial planes of isoclinal folds about low-plunging axes. Normally steeply east-dipping axial planes of Phase I folds flatten in dip, then steepen again upward to the west.

In the southern part of the Salmo area the fold axes swing to the west in strike and steepen in plunge. Strike faults that separate the Eastern, Black Argillite, and Mine belts, and which in general dip to the east, also swing westward in strike and flatten in dip.

In brief, in the Salmo area two phases of folding can be recognized which, though complicated by intrusion, faulting, and the abrupt curvature of the arc, show the same patterns as are found to the north.

STRUCTURE IN THE CENTRAL LARDEAU

The structure in the central part of the Lardeau district is characteristic of the northwesterly trending part of the arc. The pattern of folding is shown on Section A-A′ of Figure 12. The northeastern part of the section is along a tributary of Lardeau Creek, named Gainer Creek, which cuts deeply across the structure. The southwestern part of the section crosses Silvercup Ridge northeast of Trout Lake. In general the rocks are folded about axes with a low plunge into folds which have the cross-sectional form of the letter N as seen looking to the northwest. The shape of the folds in the oldest rocks near the eastern end of the section is outlined by the Badshot limestone. On Badshot Mountain about 10 miles northeast of Trout Lake the limestone dips steeply to the southwest on the southwestern limb of an almost isoclinal anticline. Northeast of the anticline the limestone lies in the trough of a tight syncline, and the anticline and syncline together form an N-shaped fold. Southwest of Badshot Mountain the limestone, or a limestone stratigraphically close to it, is repeated several times in a series of isoclinal folds which together have the same N-shaped form.

To the southwest, and higher in the stratigraphic succession, folds are outlined by the Ajax quartzite, a blocky grey massive quartzite a few tens to several hundred feet thick. Three miles southwest of Badshot Mountain the Ajax quartzite dips steeply to the southwest. It overlies an isoclinally folded and sheared series of phyllites and limestones, and the base of the quartzite is a smooth shear plane. The quartzite itself and the overlying argillites, quartzites, and volcanic rocks are folded into a series of more or less concentric folds which are step-like and N-shaped in section. About 3 miles farther to the southwest the quartzite appears on both limbs of a large anticline known as the Silvercup anticline. The anticline and the next syncline to the northeast together have the N-shaped form. Southwest of the Silvercup anticline as far as Trout Lake there are no major folds which again bring the quartzite or older rocks to surface.

The major folds in the central Lardeau were originally considered to be Phase I structures (*see* Fyles, 1962), but subsequent work by Read (Petrology and Structure of Poplar Creek Map-area, *Univ. Calif.*, Ph.D. thesis, 1966) in the Poplar Creek area, west of Duncan Lake, and reconnaissance by the writer and by the Geological Survey of Canada has shown that the Silvercup anticline and the syncline northeast of it are continuous with Phase II folds in the Duncan Lake area. Read has recognized large obscure Phase I folds in the Poplar Creek area, but only rare small folds, possible Phase I structures, have been found in the central Lardeau near Ferguson. Phase I structures may be relatively insignificant in the rocks of the central Lardeau, which are structurally higher than those to the southeast, or they may be mainly very obscure faults almost parallel to formational boundaries which have been intensely folded by the Phase II structures.

The only significant faults recognized are steeply dipping complex strike faults more or less parallel to the axial planes of the major folds. They extend southeastward into the Duncan and Kootenay Lake areas and are found also in the Poplar Creek area, and in these latter areas they are parallel to the axial planes of Phase II folds.

OTHER PHASES OF DEFORMATION

The two phases of deformation described in the foregoing pages are only part—the oldest known part—of the deformation of the Kootenay arc. Details of the complete structural history are still poorly known, and no additional fold or fault patterns of regional extent are recognized with certainty. Phase I and Phase II structures are more or less warped, sheared, broken by faults, or intruded by igneous and plutonic masses in all areas in which detailed studies have been made.

The Nelson and Kuskanax batholiths and many of the granitic stocks have local zones of intense deformation around their margins. On the northern edge of the Nelson batholith the Slocan fold is buckled downward within a mile or so of exposed granitic rocks. On the eastern edge of the batholith north of Ainsworth, Phase I and Phase II folds are warped sharply upward within half a mile of the granitic rocks (*see* p. 36). The Hidden Creek stock in the Salmo district is surrounded by a zone in which the regional strike is deflected into near parallelism with the margins of the stock. A few miles to the north, the Porcupine Creek stock is ringed by upturned sedimentary rocks. The Fry Creek batholith on the east side of northern Kootenay Lake has a shattered zone on the northwest margin, and farther east the White Creek batholith has a spectacular peripheral deformed zone. It is possible that warps preceded and controlled the emplacement of the granitic masses, and that forceful intrusion further deformed the wallrocks and produced local marginal zones of faulting.

Fold axes near plutonic masses commonly plunge steeply, but steeply plunging folds are also found far from plutonic masses, associated with cross-warps or strike-slip movements of one sort or another. Patterns of small steeply plunging folds have been delimited by detailed studies of local areas, and large-scale trends in strike are outlined on regional maps. Correlations of such patterns and trends have yet to be made. One key to a complete understanding of the structural history, the sequence of igneous and plutonic rocks, is still to be studied.

SUMMARY

The preceding descriptions attempt to show a unity of structural patterns throughout the arc. Correlations have been made on the basis of fold styles and cross-sectional shapes, and structural continuity may be more apparent than real. Although time sequences are implied, little is known of the relative ages of deformation, and it is not certain that Phase I or Phase II folds each developed throughout the arc during one specific time interval. The style and shapes of the folds depend on the structural level, which, judging from the plunge, involves several miles, the deepest levels being along Kootenay Lake. In addition to contrasting levels, there are local causes of structural inhomogeneity within the arc. These matters require further study to amplify the details, provide better correlations, and permit a full structural analysis of the arc as a whole.

Regional patterns of Phase I folds, together with the fact that the rocks become progressively older toward the east, indicate that Phase I folds are stepped upward toward the east in the form of parasitic folds on the western side of the Purcell anticlinorium. A regional movement of west up and over east is implied. Phase I may well have originated as relatively open folds which were tightened and attenuated by the Phase II deformation. Phase I folds continue to the north beyond the arc (*see* Wheeler, 1964; Ross, 1966). To the west and northwest there is a marked structural break and discordance of trend between these and the oldest folds of the Shuswap terrane (*see* Reesor, 1965).

Phase II folds southward from the south Lardeau have a cross-sectional reversed N shape, and the axial planes change systematically in attitude. In section the axial planes fan upward, forming a fold with a low plunge which is concave to the west. The axis of this fold of axial planes curves with the arc, suggesting that the curvative of the arc developed in part later than the Phase II folds. Phase II folds die out rapidly in going east from the Kootenay arc and have not been correlated with fold structures in the Shuswap terrane. Phase II folds in the central Lardeau extend to the northwest at least as far as the Columbia River.

LEAD-ZINC MINERALIZATION

Studies of the various lead-zinc districts in the Kootenay arc which have shown some of the regional patterns of the structure have also shown regional patterns of the mineralization. Detailed studies of mineralogy, element distribution, and paragenesis have not been made by the Department, but several significant studies have been made by others. As early as 1951, while the structure of the Salmo camp was still poorly understood, Green (1954) studied wallrock alteration associated with some of the Salmo deposits. Subsequently Sinclair made isotopic analyses of the lead from galenas in deposits within the arc and beyond it (*see* Sinclair, 1964 and 1966) as well as analyses of trace elements in galena. Mineralographic studies of specimens from some of the deposits have been made by students at the University of British Columbia. Muraro, who worked extensively on the Duncan deposits (*see* Muraro, 1962 and 1966), has made an interesting analysis of the relationships between the Metaline, Salmo, and Shuswap deposits, suggesting that the Salmo and Shuswap may be deformed and metamorphosed equivalents of the Metaline deposits. The following summary of the general characteristics of the lead-zinc deposits is based in part on these studies, which are continuing.

TABLE 3.—LEAD-ZINC DEPOSITS

Deposit	Sulphides in Addition to Galena, Sphalerite, and Pyrite	Gangue	Form of Orebodies	Structural Control of Orebodies	Formation
Metaline district.		Dolomite rock, calcite, quartz.	Irregular low-dipping tabular, sub bedded.	Adjustment related to regional faulting and fault zones.	Upper Metaline limestone.
Reeves MacDonald.	Pyrrhotite near lamprophyre dykes.	Dolomite rock, calcite, minor barite.	Elongate, trough-like, irregular in detail.	Steeply plunging isoclinal syncline.	Reeves limestone.
Jersey, H.B., Aspen, Jackpot.	Pyrrhotite, arsenopyrite.	Dolomite rock, calcite, tremolite-talc and garnet-diopside alterations.	Elongate bodies, low plunge, irregular in detail.	Long dimension parallel to main fold axes.	Reeves limestone.
Duncan.	Pyrrhotite, chalcopyrite.	Dolomite rock, cherty dolomite, calcite.	Elongate bodies, low plunge, irregular in detail.	Long dimension parallel to main fold axes.	Badshot limestone.
Bannockburn "Shelagh Vein."	Tetrahedrite.	Calcareous quartzite.	Elongate, low plunge.	Long dimension parallel to main fold axes.	Uppermost Hamill Group.
Jordan River.	Pyrrhotite.	Calcareous schist, quartz, minor barite.	Bedded.	Folded with the metamorphic sequence.	Shuswap metamorphic complex.
Ainsworth Camp.	Pyrrhotite, chalcopyrite, arsenopyrite.	Quartz carbonates, fluorite.	Tabular.	Veins in normal faults.	Milford Group.
Bluebell.	Pyrrhotite, chalcopyrite, arsenopyrite.	Quartz carbonates, limestone.	Irregular.	Replacement of limestone outward from fractures.	Badshot.
Sandon Camp.	Arsenopyrite, tetrahedrite, chalcopyrite, ruby silver.	Quartz, siderite, calcite.	Tabular to irregular.	Veins in regional shear-faults. Oreshoots strongly controlled by structure of wallrocks.	Slocan Group.
Zincton—Lucky Jim.		Calcite, limestone, dolomite rock.	Irregular.	Replacement of limestone outward from fractures.	Lucky Jim limestone in Slocan Group.
Cork Province.	Chalcopyrite.	Siderite, quartz, calcite.	Lenses within a shear zone with steep plunge.	Irregularities in shear zone.	Slocan Group.
Whitewater.	(1) Tetrahedrite, chalcopyrite. (2) Pyrrhotite, chalcopyrite.	(1) Siderite, quartz. (2) Magnetite, altered dyke rock.	Lenticular, moderate plunge.	(1) Irregularities within a shear zone. (2) Limestone replacement. (3) Replacement of a lamprophyre dyke.	Slocan Group.
Silver Cup.	Tetrahedrite, chalcopyrite, ruby silver.	Quartz, siderite.	Lenticular, steep plunge.	Minor drag on shear zone.	Lardeau Group, Triune Formation.

CLASSIFICATION AND STRUCTURAL RELATIONSHIPS

Detailed descriptions of many of the lead-zinc deposits in the Kootenay arc have been given in various publications. The following table summarizes salient features of selected deposits whose locations are shown on Figure 12.

The table emphasizes parallel characteristics and attempts to group the deposits for comparative purposes. The largest and most productive group are the concordant deposits, which include the Metaline and some of the Leadpoint deposits, the large mines in the Salmo area, the Duncan and Bannockburn deposits in the south Lardeau, and most of the large deposits in the Shuswap terrane. On the basis of

Rock Types	Metamorphic Minerals	Grade and Type of Metamorphism	Age	Age of Mineralization	Classification
Silicified dolomite breccia.	Chlorite, muscovite.	Low-grade regional metamorphism.	Middle or late Cambrian.	Uncertain.	Metaline type.
Dolomitized zone in limestone in a sequence of phyllites and argillites.	Muscovite, chlorite, chloritoid.	Low regional.	Lower Cambrian.	Pre-lamprophyre, during regional folding and metamorphism.	Salmo type.
Dolomitized zones in limestone, in a sequence of phyllite, argillite, and hornfels near granitic stocks.	Biotite, garnet diopside, zoisite.	Biotite grade regional, with superimposed contact metamorphism.	Lower Cambrian.	Pre-"granite" but some mineralization post contact metamorphism (H.B.).	Salmo type.
Dolomitized and siliceous zones in limestone.	Biotite, chloritoid, garnet.	Biotite and garnet grades, regional metamorphism.	Lower Cambrian.	During regional folding and metamorphism.	Salmo type.
Calcareous quartzite, phyllite, limestone.	Clorite, muscovite.	Low regional metamorphism.	Lower Cambrian.	During or after regional folding.	Salmo type.
Calcareous schists, marble and quartzite.	Garnet sillimanite.	High-grade regional metamorphism.	Uncertain.	Pre-metamorphism and folding.	Shuswap type.
Limestones, mica and hornblende schists, quartzites.	Garnet, staurolite, biotite.	Biotite and garnet grades, regional metamorphism.	Late Palæozoic.	Post lamprophyre, post folding and metamorphism.	Vein type.
Crystalline limestone, quartzite, and schist.	Kyanite-sillimanite.	High-grade regional metamorphism.	Lower Cambrian.	Post lamprophyre, post folding and metamorphism.	Fracture controlled replacement.
Dark-grey argillites, siliceous and limy argillites.	Muscovite, chlorite, sericite.	Low-grade regional metamorphism.	Triassic.	Late stages of folding; post lamprophyre, post Nelson.	Complex vein systems.
Fine-grained limestone.	Muscovite.	Low-grade regional metamorphism.	Triassic.	Post lamprophyre.	Fracture controlled replacement.
Slates, argillites, thin limestones.	Biotite.	Low-grade regional and thermal metamorphism.	Triassic.	Uncertain.	Complex shear zone.
(1) and (2) Limestone. (3) Lamprophyre dyke.	(1) and (2) Chlorite muscovite. (3) Chrome mica.	Low-grade regional metamorphism.	Triassic.	Late stages of deformation(?), post lamprophyre.	Complex shear zone.
Slates.	Muscovite, chlorite, siderite, chrome mica.	Low-grade regional plus widespread hydro-thermal alteration.	Mid-Palæozoic.	Uncertain.	Complex shear zone.

their structural characteristics they are referred to as three more or less distinct types—the Metaline, the Salmo, and the Shuswap types. Transgressive deposits are more diverse in form and more difficult to classify. Most important are the lodes and veins of the Slocan camp, followed in importance by fracture-controlled replacements such as the Bluebell and Lucky Jim. Complex shear zones at the Cork Province and Whitewater and Silver Cup in the Lardeau contain fairly large as well as small orebodies. Simple veins like those in the Ainsworth camp, in the Nelson batholith, and in the central mineral belt of the Lardeau are widespread and carry relatively small orebodies.

The *concordant deposits* in general are disseminations of pyrite, sphalerite, and galena with or without pyrrhotite in a calcareous host rock. The dominant gangue is the host rock or its alteration products and consists mineralogically of dolomite, calcite, quartz, and rarely barite. Careful studies of the Salmo (Fyles and Hewlett, 1959, p. 84) and Metaline type deposits (Dings and Whitebread, 1965) indicate that the quartz and dolomite formed by silicification and dolomitization of calcareous rocks, mainly limestones, before sulphide mineralization and at least in part before deformation. Much of the calcite appears to have developed from the dolomite at the same time as the sulphides. Certain dolomitized and silicified zones were selectively replaced by the sulphides. Silicification and dolomitization were much more widespread than sulphide mineralization, and their ultimate control is not known. Sulphide mineralization, however, is localized by the structure—in the Salmo type deposits by tight folding and in the Metaline by faulting and brecciation.

Rocks associated with the Metaline type deposits have been folded once; those with the Salmo type have undergone multiple folding. Specifically, in the Salmo and adjacent Metaline areas the primary or Phase I folds affected both areas, but the secondary or Phase II folds are insignificant or non-existent in the area of Metaline deposits. Sulphide mineralization in the Salmo area is associated with the Phase II folds and may have been controlled as well as deformed by them, whereas faults, and adjustments related to faulting, superimposed on Phase I folds form the dominant control of the Metaline deposits. Patterns of folding in the Duncan Lake area parallel those in the Salmo area, and the control of sulphide mineralization is the same. They are therefore regarded as a Salmo type of deposit. By analogy the distinction between the Metaline and Salmo type deposits can be extended beyond the arc. The Mineral King deposit in the Purcell Mountains and the Monarch in the Rockies are Metaline type deposits and occur in rocks that have undergone only a single period of major folding.

The Shuswap type deposits occur in calcareous schists in rocks in a medium to high grade of regional metamorphism. Clean marbles commonly present in the mineralized sequences are largely unmineralized. The sulphides tend to be more massive than in the Salmo and Metaline types and include augen-like blebs of watery quartz and attenuated minor folds. In the Jordan deposit and probably in most of the others such as at Ruddock Creek, the Cotton Belt, and the Big Ledge, the sulphides are confined to one layer, which seems to be an original bed. They are remarkably extensive but narrow and may be thickened by folding. Deformation and metamorphism obscure much of the evidence of genesis.

The *transgressive deposits* are veins, vein systems, and shear zones which cut across various types of rock and various structures. The form of the orebodies is controlled by the vein or shear and the wallrocks. In the Ainsworth camp, movements on normal faults and contrasting competencies in the wallrocks have been the principal control. In the Sandon area a series of complex shear zones in relatively incompetent rocks have oreshoots scattered along them. Folding accompanied movements on the shear zones, and orebodies were localized in the shear zones mainly by the folds. In the central mineral belt of the Lardeau near Ferguson, a fault zone of regional extent obliquely transects an anticlinal crest, and a series of veins associated with these structures has been mineralized. Shear zones which lie subparallel to the regional foliation, such as the Silver Cup in the Lardeau and the Whitewater and Cork Province in the Slocan, contain complex orebodies commonly with a steep plunge related to lateral movements within the zone. Replacement deposits at the Bluebell and Lucky Jim are more or less closely controlled by fractures in limestones. Thus the transgressive deposits have a variety of forms, depending mainly on the structures in which they occur and on a variety of characteristics in the wallrocks.

AGE OF MINERALIZATION

The absolute age of the deposits as we now see them has been discussed by Sinclair (1966, p. 251), who considers the Slocan veins to be not older than 170 million years (Middle Jurassic). He further estimates that for all the deposits he studied, " The maximum duration of mineralization is estimated to be about 150 million years." These conclusions are based on geological evidence as well as on a study of lead isotopes. They agree with the regional geological evidence that major deformation, metamorphism, and granitic intrusion of the Kootenay arc is Mesozoic and Tertiary.

Sinclair's studies of lead isotopes indicate that the lead of the Kootenay arc deposits had a relatively complicated history before being emplaced in the present mineralized zones. The age relationships determined geologically concern this latest mineralization process, which took place well after most of the host rocks were deposited. The criteria for relative age are commonly difficult to interpret and may lead to conflicting conclusions. They show various stages in a complicated mineralization process. Gross relationships lead to the following conclusions:—

(1) The concordant deposits are relatively old.

(*a*) All are older than a suite of lamprophyre dykes. These dykes are undeformed, of very similar composition and texture, and have been regarded as a consanguineous suite of Tertiary age. Absolute age determinations which might establish this age and relative ages within the suite have not yet been made.

(*b*) At least one orebody at the Jersey mine is cut by a granitic dyke, which is an offshoot of a granitic stock, the Jersey stock, belonging to the Nelson plutonic suite.

(*c*) At the H.B. mine some galena and sphalerite are found along cleavage planes of tremolite, which has formed by thermal metamorphism associated with granitic stocks close to the Jersey stock. Thus the galena is younger than the thermal metamorphism, and the evidence conflicts with that at the Jersey and requires explanation.

(*d*) On a regional basis, orebodies of the Salmo type are associated with structures that are older than the Nelson plutonic rocks.

(*e*) Ore textures studied and illustrated by Muraro (1966, p. 245) clearly show that the sulphides of the Salmo and Shuswap deposits have undergone penetrative deformation.

(*f*) The Jordan and probably the other Shuswap deposits have undergone intense regional metamorphism. Whether or not the Salmo type deposits have been subjected to regional metamorphism is uncertain.

(2) The transgressive deposits are relatively young.

(*a*) The best data of the relative age of mineralization and lamprophyre intrusion are from the Ainsworth and Slocan camps. At Ainsworth and at the Bluebell sulphide mineralization is younger than the lamprophyres. In the Slocan also the mineralization is younger than most, if not all, the lamprophyres (*see* Cairnes, 1934, p. 73; Hedley, 1952, p. 26; Hedley, 1947, pp. 24 and 45). Although a regional petrogenetic study of the lamprophyres is yet to be made, these relationships suggest that the transgressive deposits are significantly younger than the concordant deposits.

(*b*) The mineralization and the lamprophyres are both younger than all facies of the Nelson plutonic rocks.

The Nelson granitic rocks, which include the Nelson and Kuskanax batholiths and a number of related stocks mainly in the southern part of the arc, as now exposed, seem to have been incidental to the mineralization process. Early workers regarded the Nelson plutonic rocks as the source of the lead-zinc mineralization, but careful studies have not found evidence that any one deposit or group of deposits is gentically related to a specific pluton. The corcordant deposits appear to be older than the exposed granitic rocks. Some deposits are peripheral to the Nelson batholith and some are within it, but there is no evidence of regional zoning related to the batholith. If ore-forming solutions were derived from some magma chamber, it must have been deeper than the presently exposed granitic rocks. The best we can conclude is that the immediate source of the mineralizing solutions is unknown, and it is hoped that continuing geochemical studies will help in localizing the source. It is expected that the immediate source for the concordant deposits was widespread and uniform, and for the transgressive it was more local.

Composition of the Mineralized Zones

The mineralogical and chemical compositions of the lead-zinc ores in the Kootenay arc have not been studied on a systematic regional basis. In general, the concordant deposits have a simple mineralogy and the transgressive deposits a more complex one. Pyrite, sphalerite, and galena are the principal sulphides of the concordant deposits. Pyrrhotite, common in the Shuswap deposits, is found in some deposits of the Salmo type and is not found in the Metaline deposits. In the Reeves MacDonald the only pyrrhotite known is adjacent to a lamprophyre dyke and appears to have formed by thermal metamorphism of pyrite. It has been suggested that pyrrhotite in the other Salmo type deposits may have developed by thermal or regional metamorphism (*see* Muraro, 1966, p. 247). Sphalerite varies widely in colour and in iron content, and the suggestion has been made that darker-coloured sphalerites are produced in part by metamorphism. Metamorphism of the sulphides, however, has not been adequately studied.

Although galena, sphalerite, pyrite, and pyrrhotite are the most common sulphides of the transgressive deposits, a number of other sulphides are relatively abundant. These include chalcopyrite, arsenopyrite, argentiferous tetrahedrite, and a number of silver minerals. Native silver is common in the Slocan and has been found in a few other areas.

The major element content in general reflects the gross mineralogy and shows significant differences between the transgressive and the concordant types of deposits. The concordant types are lower in lead and zinc than the transgressive, simply because massive sulphides, though present, are uncommon in the concordant deposits. Lead, zinc, and silver ratios vary widely, and patterns of distribution are not evident from the inspection of production figures. All the deposits contain trace amounts of cadmium, of which there has been significant production. Abnormally high trace amounts of tin in sphalerite (*see* Warren and Thompson, 1945) and galena (*see* Sinclair, 1964) are found in most of the deposits and appear to be characteristic of a general region extending beyond the arc. Geochemical studies are continuing, and it is expected that analyses of production figures and of drill-core assays as well as studies of minor elements will show patterns of distribution which may point to the source of the mineralizing solutions.

CHAPTER V.—NOTES ON PROPERTIES

ALBION

Location.—Three-quarters of a mile south-southwest of Ainsworth.

Status.—Crown-granted claim owned by Yale Lead & Zinc Mines Ltd.

History.—Crown granted in 1899 by the Albion Mining Co., and worked intermittently until 1906. The property was acquired by Yale Lead & Zinc Mines Ltd. in 1949 and worked until 1958.

Workings.—Albion crosscut and raise, now part of the Highlander mine.

Geology.—*See* page 83.

Map.—*See* Figure 19, in pocket.

AMAZON

Location.—Canyon of lower Woodbury Creek.

Status.—Cancelled Crown-granted claim relocated in 1965 by L. D. Besecker, of Ainsworth.

History.—Crown granted in 1894. The claim was acquired in 1948 by Besecker and worked in 1952, 1953, 1956, and 1965 by several small companies.

Workings.—An adit collared in 1952 on the south bank of Woodbury Creek just above the Balfour–Kaslo highway follows the south and west banks of the creek.

Geology.—*See* page 115.

Map.—*See* Figure 31, page 116.

AUGUST FRACTION

Location.—Kootenay Lake shore just north of the Woodbury delta.

Status.—Crown-granted claim owned by L. D. Besecker, of Ainsworth.

History.—This claim was Crown granted in 1904 by the King Solomon Mining Co. Ltd. A vein in a shore cliff just above Kootenay Lake was worked between 1948 and 1951 by Besecker and associates.

Geology.—*See* page 115.

Map.—*See* Figure 31, page 116.

AYESHA

Location.—North side of Cedar Creek about 2½ miles west of Kootenay Lake, elevation 3,700 feet.

Status.—Crown-granted claim owned by G. E. Penrod, of Colfax, Wash.

History.—The claim was Crown granted in 1891 but there is no record of early work on the property. Considerable work was done between 1948 and 1954 by lessees and a number of small companies.

Geology.—The Ayesha property covers several layers of fine-grained blue-grey to light-grey limestones separated by fine-grained grey knotted schist. These rocks are in the third fault slice and the limestones are part of the Star limestone (*see* p. 30). They strike between north and north 20 degrees east and dip to the west at moderate angles. At least three limestone layers a few tens of feet thick are exposed. They are lenticular and have a branching outcrop pattern suggesting structural repetitions and " tails " produced by isoclinal folding, but the details of such folding are obscured by the scattered nature of the outcrops.

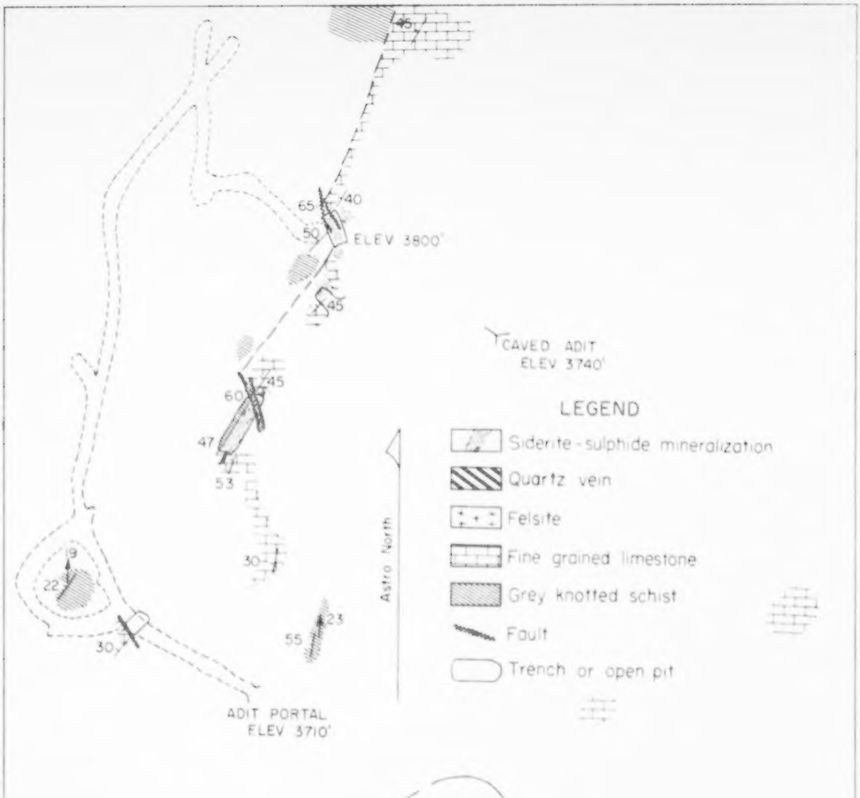

45
65
40
50
ELEV 3800'
45
CAVED ADIT
ELEV 3740'
45
60
47
53
30
19
22
30
23
55
ADIT PORTAL
ELEV 3710'
Astro North
LEGEND
Siderite - sulphide mineralization
Quartz vein
Felsite
Fine grained limestone
Grey knotted schist
Fault
Trench or open pit
73
18
ROAD
56
20
40
47
70

Figure 13. Map of the underground workings and surface geology on the Ayesha property.

The principal showings are along the western contact of one layer of limestone where it is transected by three faults. The faults which strike northwest and dip 60 to 65 degrees to the southwest have offset the contact 15 to 20 feet to the left. The showings consist of lenses of rusty-weathering siderite in the limestone and contain galena, sphalerite, pyrite, and minor chalcopyrite. The siderite replaces the limestone near the faults and occurs as a vein-like filling along the faults. The most extensive replacement is near the faults, where, in one place, siderite with scattered sulphides forms a lens as much as 4 feet thick extending about 30 feet from a fault.

The mineralization is exposed in several surface workings but was not encountered in an adit driven beneath these workings (*see* Fig. 13). The adit is in the limestone and crosses the faults, which are not mineralized, but does not penetrate the hangingwall of the limestone where it is cut by the faults, a place where mineralization is to be expected. A raise from the adit encountered mineralization near the surface and some ore has been shipped (*see* p. 44).

About 300 feet southeast of the adit portal, an old trench partly destroyed by a logging-road exposes a 6-foot quartz vein containing pyrite. The vein is parallel to the foliation and lies on the hangingwall of a layer of limestone that strikes north 20 degrees east and dips to the west at 45 to 50 degrees.

BANKER

LOCATION.—Half a mile southwest of Ainsworth.

STATUS.—Crown granted, owned by Yale Lead & Zinc Mines Ltd.

HISTORY.—The Banker claim was surveyed in 1888 for A. D. Wheeler and originally developed about 1905. It was worked by Cominco Ltd. during the first world war and again in 1927 and 1928. For many years it was owned by Henry Giegerich, of Ainsworth, and worked by lessees or small companies. It was bought by Yale Lead & Zinc Mines Ltd. in 1949 and worked as part of the Highlander by the company until 1958 and by lessees in 1959.

WORKINGS.—Lower Banker crosscut and extensive drifts, raises, and stopes are connected through the work by Yale with the Highlander mine.

GEOLOGY.—*See* page 83.

MAP.—*See* Figure 19, in pocket.

BELL

LOCATION.—South side of Lendrum Creek, three-quarters of a mile west of Kootenay Lake.

STATUS.—Reverted Crown grant. In 1965 the ground was open.

HISTORY.—The principal work on the property was done between 1948 and 1952, when W. J. Turner, of Ainsworth, obtained this claim and others nearby and optioned them to Woodbury Mines Limited. In 1952 after about 3,000 feet of diamond drilling, an old adit on the south bank of Lendrum Creek, in the canyon, was extended and drifting was done on a narrow quartz-carbonate vein.

WORKINGS.—*See* Figure 14.

GEOLOGY.—The rocks on the claims are fine-grained grey mica schists with thin interlayers of blue-grey crystalline limestone. The limestone may be correlated with the lower Ainsworth, but is separated from outcrops of the lower Ainsworth by a large covered area (*see* Fig. 3). The thickest layer exposed in Lendrum Creek and at the adit portal and followed underground is 20 to 50 feet thick. The adit intersects a quartz-carbonate vein up to a foot thick that strikes between north 55 degrees east and due east and dips steeply to the south. Toward the east it frays and turns southward into the foliation. Near the limestone the vein contains 6 to 8

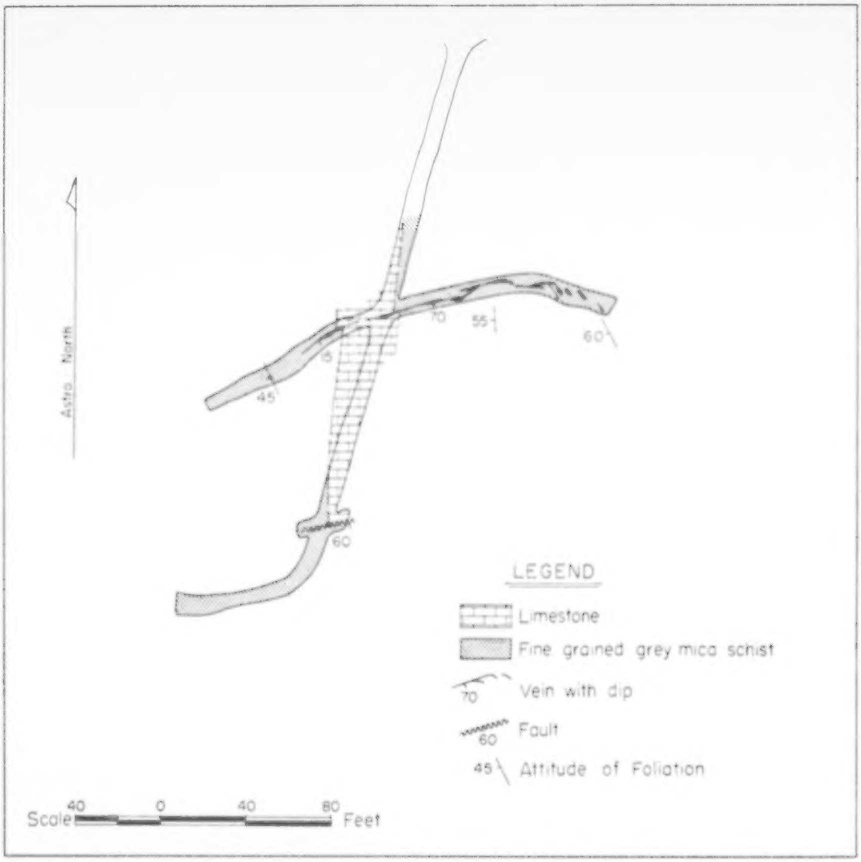

Astro North
70
55
60
15
45
60
LEGEND
Limestone
Fine grained grey mica schist
70
Vein with dip
60
Fault
45
Attitude of Foliation
Scale 40 0 40 80 Feet

Figure 14. Sketch-map of the adit on the Bell claim.

inches of coarse galena. On the surface, broken rock near the outcrop of the vein includes pieces of banded quartz and calcareous rock containing pyrite, sphalerite, galena, and rusty carbonates, but none of this material was found in place.

BELLE AIRE

Location.—The Belle Aire showings are on the north side of Coffee Creek about 250 feet west of the Balfour–Kaslo highway bridge.

Status.—The showings in 1965 were covered by a claim held by record by Mrs. A. V. Hallgren, of Nelson.

History.—The property was owned for many years by Sven Hallgren, who lived on the south side of Coffee Creek near the showings. He extended an old adit by intermittent work between 1950 and 1958, shipping 4 tons of ore in 1950.

Workings.—On the north side of Coffee Creek an adit 120 feet long with portal 250 feet west of the Balfour–Kaslo highway and 50 feet above Coffee Creek has been driven northward along a narrow lenticular quartz vein.

Geology.—The quartz vein, in mica and garnet mica schist, strikes north 10 degrees east and dips 60 degrees to the west, parallel to the foliation of the schists.

It is 18 inches wide at the portal but becomes more narrow and lenticular in the adit. The hangingwall is a fault plane with slickensides parallel to the dip.

BLACK DIAMOND

LOCATION.—Three-quarters of a mile southwest of Ainsworth.

STATUS.—Crown-granted claim owned by Yale Lead & Zinc Mines Ltd.

GEOLOGY.—*See* page 83.

BUCKEYE

LOCATION.—Between Cedar and Princess Creeks, 1 mile west of Kootenay Lake.

STATUS.—Crown-granted claim owned by Guichon Mine Limited.

WORKINGS.—*See* Figure 15.

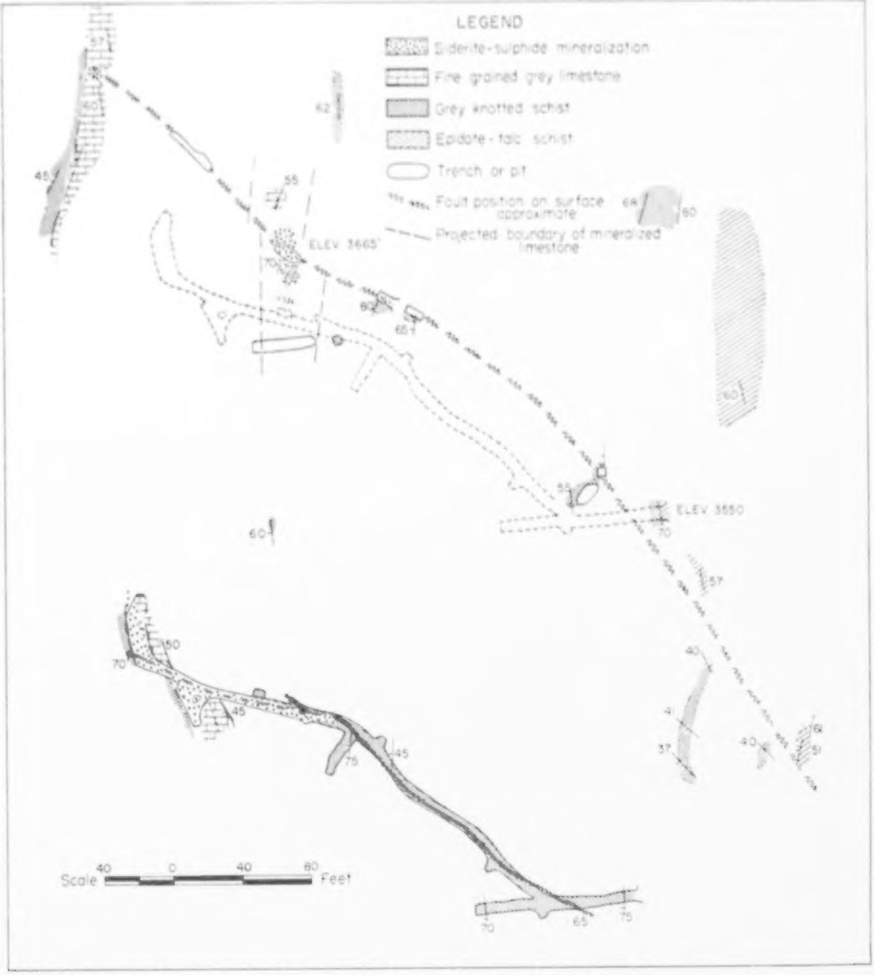

LEGEND
Siderite-sulphide mineralization
Fine grained grey limestone
Grey knotted schist
Epidote - talc schist
Trench or pit
Fault position on surface approximate
Projected boundary of mineralized limestone
ELEV 3665'
ELEV 3550
Scale
40
0
40
80
Feet
57
60
45
62
55
70
60
65
68
50
75
37
41
40
51
61

Figure 15. Geological map of showings on the Buckeye property.

History.—The Buckeye and adjoining Buckeye No. 2 fractions were originally owned by W. C. Dalgliesh, of Patterson, New Jersey, who did considerable work before 1918. In 1952 the claims were owned by Guichon Mine Limited, and most work on the property has been done by this company and by lessees between 1952 and 1954.

Geology.—The principal rock types on the Buckeye claim are grey knotted schists and fine-grained blue-grey limestone part of the Star limestone. A thin layer of epidote and talc schist occurs near the adit portal and continues for several hundred feet to the north.

The main adit follows a fault, exposed also in a number of pits and shallow workings, that strikes in general north 65 degrees west and dips at 70 degrees to the south. The fault causes a left-hand offset of the formations that increases from a few feet in the westernmost exposures to as much as 100 feet east of the adit portal. The change in offset is probably caused by a tendency for the fault to curve northward into the foliation and for movement to be taken up along foliation planes. Fractures that strike more nearly east and dip more steeply south than the general attitude of the main fault are common particularly in the hangingwall of the fault.

The principal mineralization is found where the fault transects a layer of limestone 20 to 30 feet thick. In the grey schist the fault is a zone of pronounced shearing and gouge which toward the limestone contains siderite, quartz, and calcite. Adjacent to the limestone, pyrite, galena, and sphalerite are found in the vein and spread out along the hangingwall of the limestone for as much as 30 feet from the vein. Siderite replaces the limestone along fractures, many of which strike more nearly east and dip more steeply than the fault. The sulphides also follow these fractures and occur in the siderite near the fractures. The oreshoot has been mined from the level to the surface, a slope distance of about 120 feet, and in this distance the rake of the shoot is down at 60 degrees in a direction of south 70 degrees west.

BUDWISER

Location.—Canyon of lower Woodbury Creek.

Status.—Crown-granted claim owned by Mineral Mountain Mining Co. Ltd., of Vancouver.

Geology.—*See* page 116.

CAREY FRACTION

Location.—South side of Princess Creek less than half a mile southwest of the Florence camp.

Status.—Crown-granted claim owned by Western Mines Limited.

Workings and Geology.—*See* Lakeshore, page 99.

CROW FLEDGLING

Location.—Along Krao Creek 2,000 feet west of the south end of Loon Lake.

Status.—Crown-granted claim owned by Yale Lead & Zinc Mines Ltd.

Workings.—*See* Figure 25. The workings consist of a short shaft and several open cuts along the course of Krao Creek and a long crosscut, called the McCune crosscut, with portal about 1,300 feet east of these workings and an estimated 250 feet in elevation below them. In 1963 air in the crosscut was deficient in oxygen more than 600 feet from the portal.

History.—The Crow Fledgling was Crown granted in 1890 by A. D. Wheeler, and some surface work was done before 1900. The McCune crosscut was driven in 1916 and 1917 under the direction of A. W. McCune. Exploration in the crosscut continued in 1929, and some mining was done by the present owners in 1955.

Ore was shipped from the surface workings at various times, the latest of which was by T. Lane in 1960 and 1963.

Geology.—Mineralization on the Crow Fledgling claim is in the Krao limestone and quartzites adjacent to it. The southernmost workings, a short shaft and a series of trenches, are on a vein along a fault striking north 70 to 80 degrees west and dipping southward at 60 to 70 degrees. Where the vein crosses the limestone, particularly near the western contact of the limestone, it contains siderite, galena, sphalerite, and pyrite in widths up to 5 feet. The mineralized zone swings northward along the western contact of the limestone for about 400 feet and contains considerable siderite and scattered pods of sulphides. The fault continues westward into the hangingwall quartzite but is not mineralized. Recent work has shown that about 400 feet north of this fault another fault striking between north 50 and north 70 degrees west and dipping 60 degrees to the south contains a pod of siderite and massive galena. The best mineralization is where the fault transects the western contact of the Krao limestone. It appears that both the faults split at this contact, partly following the contact and partly displacing it.

CROWN

Location.—Crest of ridge between Cedar and Lendrum Creeks 1¾ miles west of Kootenay Lake.

Status.—Old Crown-granted claim now held as a mineral lease by D. H. Norcross, of Nelson.

History.—The Crown is an old property on which exploration was done before 1912. In 1963, D. H. Norcross shipped 13 tons of gossan from surface workings, made a number of trenches, and cleared out and extended No. 2 adit.

Workings.—Two short adits and a number of open cuts. No. 1 adit is on the west side near the bottom of a deep draw opening southward toward Cedar Creek. No. 2 adit and most of the open cuts are on the east slope of the draw about 1,000 feet to the southeast.

Geology.—The claim covers the western contact of a thick mass of fine-grained grey and white limestone with dark-grey to black somewhat limy argillite on the west. Regional mapping suggests that this contact may be a northerly trending fault, but it is not exposed. No. 1 adit and an open pit to the northwest are in the black argillite. The adit follows closely spaced branching faults that strike between northwest and north 10 degrees west and dip steeply to the southwest. Locally they carry white quartz and pyrite.

No. 2 adit and surface workings north and south of it (*see* Fig. 16) are along the eastern contact of one or more thin layers of black argillite in limestone. The workings from which gossan running 96 ounces per ton in silver was shipped (*see* Table 1) are 250 to 350 feet south of the adit. Trenches to the north and the adit expose some gossan, a few narrow calcite-siderite veinlets, and locally minor pyrite, galena, and sphalerite.

DAISY

Location.—South of Lendrum Creek three-quarters of a mile west of Kootenay Lake.

Status.—Crown-granted claim owned by Western Mines Limited.

History.—This old claim is part of a group called the Daisy Bell obtained in 1948 by W. J. Turner and optioned in 1950 and 1951 to Woodbury Mines Limited. There is no record of any work having been done since about 1900.

Workings.—The workings are old and include a short adit and two open cuts.

Geology.—A rusty vertical fracture striking east and containing a few inches of quartz and locally galena is followed in the workings. It is in fine-grained grey mica schist.

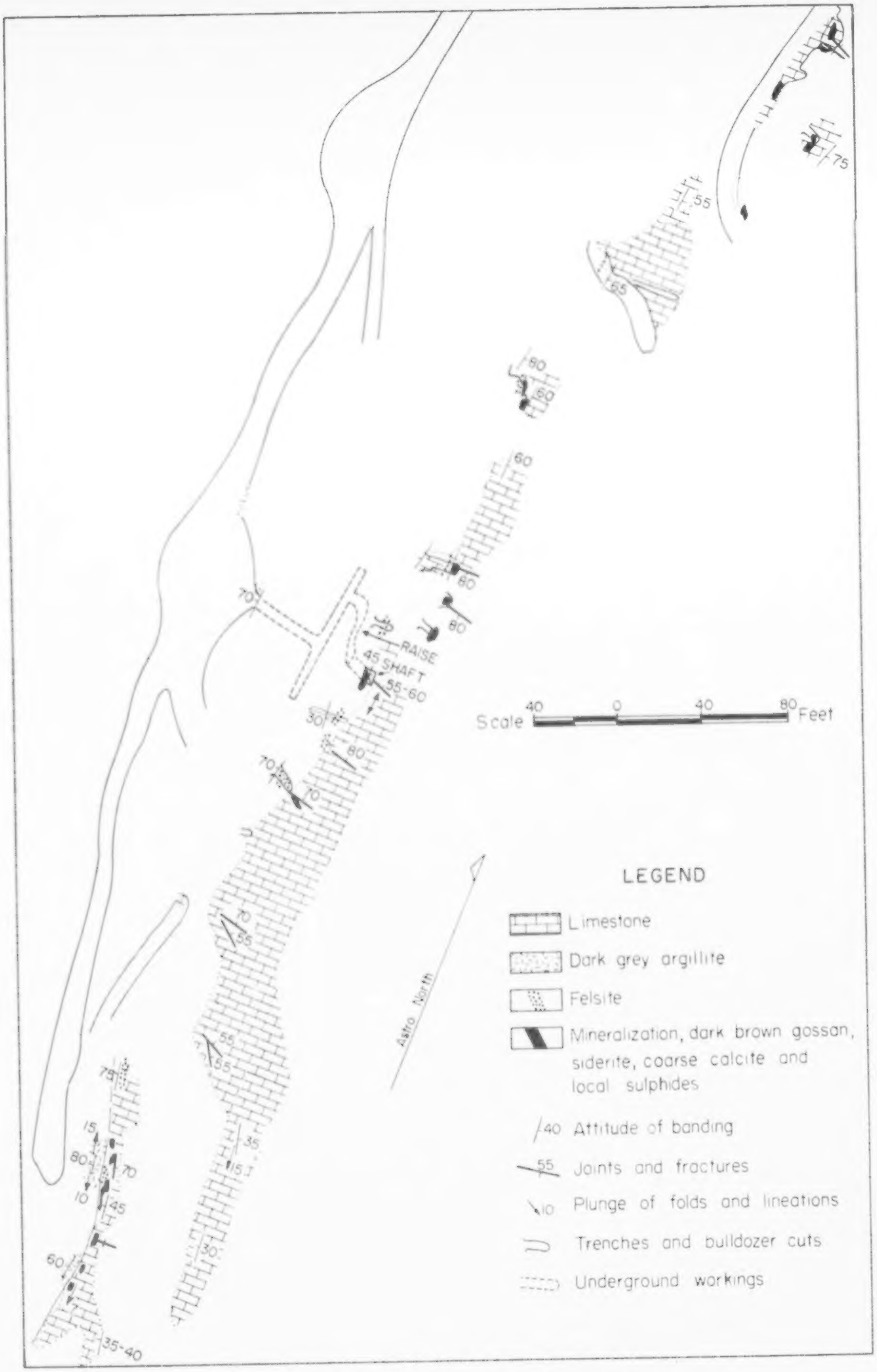

RAISE
SHAFT
45
55-60
Scale 40 0 40 80 Feet
Astro North
LEGEND
Limestone
Dark grey argillite
Felsite
Mineralization, dark brown gossan, siderite, coarse calcite and local sulphides
40 Attitude of banding
55 Joints and fractures
10 Plunge of folds and lineations
Trenches and bulldozer cuts
Underground workings
35-40

Figure 16. Map of showings on the Crown property.

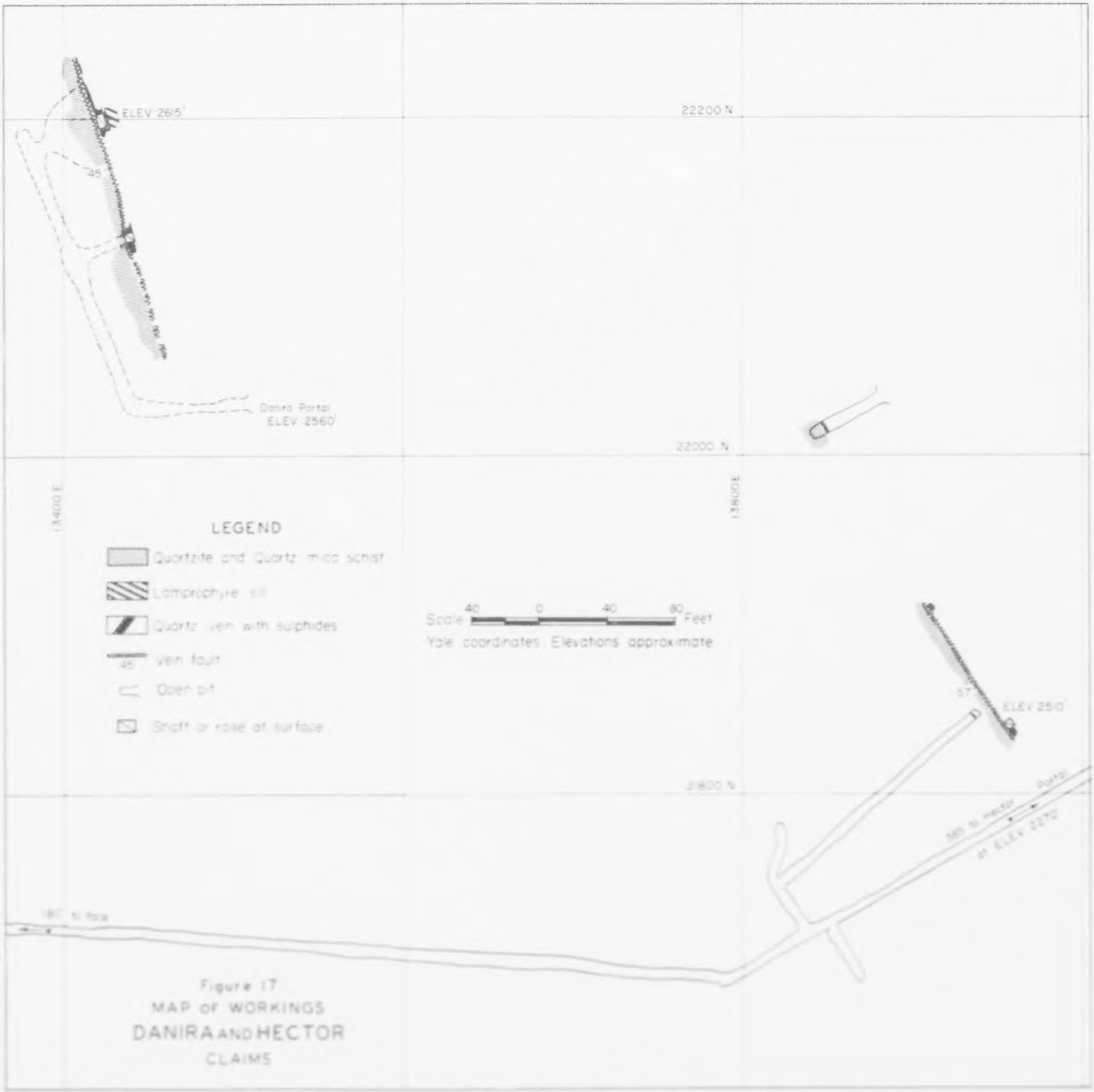

ELEV 2615'
45°
Danira Portal
ELEV 2560'
22200 N
22000 N
21800 N
13400 E
13600 E
LEGEND
▨ Quartzite and Quartz mica schist
▨ Lamprophyre sill
▨ Quartz vein with sulphides
45 Vein fault
Open pit
Shaft or raise at surface
Scale 40 0 40 80 Feet
Yale coordinates Elevations approximate
57°
ELEV 2510'
380' to Hector Portal
at ELEV 2270'
180' to Face

Figure 17
MAP OF WORKINGS
DANIRA AND HECTOR
CLAIMS

DIXIE

See page 115, Woodbury Creek.

DANIRA AND HECTOR

LOCATION.—About half a mile northwest of Ainsworth.

STATUS.—Crown-granted claim owned by Yale Lead & Zinc Mines Ltd.

WORKINGS.—*See* Figure 17.

HISTORY.—The Danira and Hector are very old claims on which considerable exploration and some mining was done by the present owners between 1951 and 1955.

GEOLOGY.—The claims cover two quartz veins that strike between north 25 and north 30 degrees west and dip 45 to 60 degrees west and are parallel to the foliation of the enclosing rocks, which are quartz-mica schists and quartzites. The vein on the Danira is on strike to the north from the Highlander vein. It follows the hangingwall of a lamprophyre sill and is a quartz vein up to 3 feet thick containing lenses of sphalerite, galena, pyrite, and minor chalcopyrite up to about a foot thick. The vein on the Hector as exposed in an old trench and shaft consists of 2 to 3 feet of rusty quartz containing lenses of galena, sphalerite, pyrite, and chalcopyrite.

EARLY BIRD

LOCATION.—Shore of Kootenay Lake, one-quarter mile south of the mouth of Princess Creek.

STATUS.—Crown-granted claim owned by F. W. Robinson, of Ainsworth.

HISTORY.—The property is an old one on which exploratory work was done intermittently between 1889 and 1910. Considerable mining was done from 1914 to 1916. The mine was worked again by the present owner between 1949 and 1951.

WORKINGS.—Two short adits have been driven westward, one in the rock cut on the Balfour–Kaslo highway and the other at high-water level below the highway, and stoping has been done between them.

GEOLOGY.—The workings are on a narrow fissue vein that strikes northwest and dips 60 degrees to the southwest and contains quatz, calcite, galena, sphalerite, and pyrite. The vein is in calcareous and siliceous mica schists and lime silicate gneisses of the Early Bird Formation.

EDEN AND CRESCENT

LOCATION.—North side of Coffee Creek about 1,500 feet west northwest of the highway bridge over Coffee Creek.

STATUS.—Crown-granted claims owned by Yale Lead & Zinc Mines Ltd.

HISTORY.—These claims were Crown granted in 1894 and were worked on intermittently, particularly between 1916 and 1918, during which time much of the present adit level was driven. In 1936 the property was worked by Robert Sherradden, of Ainsworth. The claims were acquired by Yale Lead & Zinc Mines Ltd. in 1949, and mining was carried on by this company mainly between 1951 and 1955.

WORKINGS.—*See* Figure 18.

GEOLOGY.—The claims cover a layer of crystalline grey limestone in micaceous quartzites and mica schists. The workings follow two shear zones about 250 feet apart which strike north and dip 45 degrees to the west.

The most easterly zone, followed by the adit for about 400 feet, contains highly sheared dark-grey to black schist in a zone 4 to 5 feet wide that near the portal contains lenses of quartz but no sulphides. The most westerly fault is in mica schist and micaceous quartzite just west of a prominent limestone. It contains fine-grained

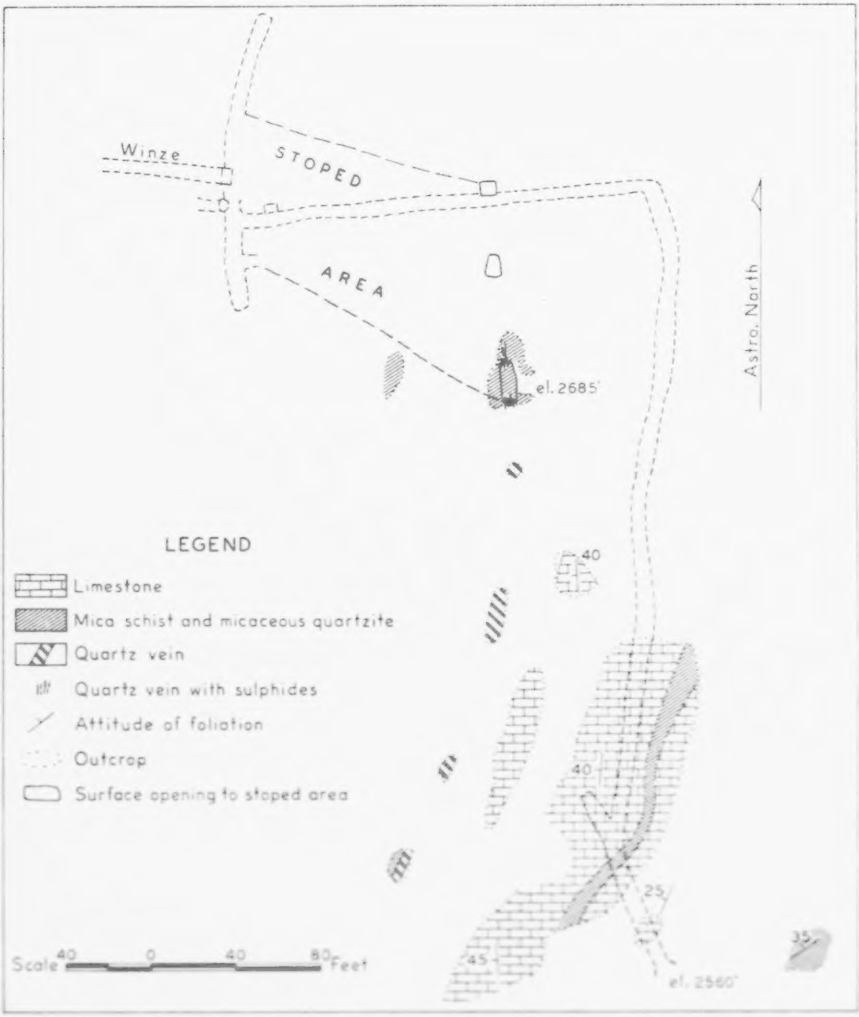

Winze
STOPED
AREA
el. 2685'
Astro. North
LEGEND
Limestone
Mica schist and micaceous quartzite
Quartz vein
Quartz vein with sulphides
Attitude of foliation
Outcrop
Surface opening to stoped area
40
40
25
45
35
el. 2560'
Scale 40 0 40 80 Feet

Figure 18. Surface geology and underground workings, Eden and Crescent mine.

quartz with many vugs, minor calcite, and siderite as well as resinous brown sphalerite, galena, and pyrite. The best mineralization, which has been mined over widths up to 5 feet, is at a place where the vein is gently curved and is convex upward toward the west. The vein was stoped above the level from 1952 to 1954 for a strike length of 50 to 100 feet, and in 1954 and 1955 a winze was sunk 120 feet on the vein below the level. Although good mineralization was exposed in the winze, it did not continue on strike to the south or north. The work suggests that the oreshoot tapered down the dip and is more or less V-shaped in plan.

FERGUS, FLORENCE M, R.F.G.

Location.—These three adjacent claims are between Princess and Lendrum Creeks about three-quarters of a mile west of Kootenay Lake. They are crossed by the main logging-road from the Florence townsite and the workings are just below the road 1¾ miles from the townsite.

Status.—Crown-granted claims. Fergus and Florence M are owned by Western Mines Limited, R.F.G. by Tom Hawes, of Ainsworth.

Workings.—The main workings are on the Florence M claim near the boundary of the Fergus and include an adit driven westward about 100 feet, from which some stoping has been done.

Geology.—The working on the Florence M claim follows a vein that strikes east and dips about 60 degrees to the south. The vein is in fine-grained hornblende schist, which near the portal of the adit contains a lens of grey crystalline limestone, and to the east below the adit portal is underlain by fine-grained grey mica schist. The vein is along a fault that offsets the limestone a few feet to the left. The oreshoot that has been mined is in the hornblende schist near its footwall contact and also near the limestone. The limestone near the vein is replaced by siderite, but the sulphides do not seem to have spread from the vein with the siderite. Ore on the dump is a fine-grained aggregate of pyrite, pyrrhotite, galena and sphalerite, quartz, and siderite. Ore remaining in the stope contains some coarse galena in a vein less than a foot thick. The vein is reported to have been up to 1½ feet thick and the stope has a maximum width of 4 feet.

FIREBRAND

Location.—About 2 miles south of Ainsworth between the Crow Fledgling and Last Chance Crown-granted claims.

Status.—Ground open in 1965.

History.—Although this is an old property, there is no published account of work done on it until 1955, when a shaft was sunk to a depth of 30 feet by Yale Lead & Zinc Mines Ltd.

Workings.—Two shallow shafts and a number of open cuts and a short adit.

Geology.—These workings are along a quartz vein that strikes north 20 degrees west and dips 60 to 70 degrees to the west parallel to the foliation in the wallrocks. The wallrocks are micaceous quartzite and quartz-mica schist lying west of a layer of hornblende schist. The vein is found intermittently along strike for about 500 feet and is 1 to 3 feet thick.

GALLAGHER

Location.—About 1½ miles due west of the Florence townsite.

Status.—Two Crown-granted claims. Let Er Go Gallagher and Gallagher Fraction owned by C. S. Wheeler, of Sacramento, Calif.

History.—From 1888 to 1890 the property was worked by A. D. Wheeler, the original owner. From 1907 to about 1920 it was again worked by Wheeler or by lessees. It has been idle since 1920.

Workings.—The original workings include a number of shafts and open pits at an elevation of about 4,200 feet. Two main shafts are reported in early descriptions. In later years an adit was driven about 270 feet in elevation below the upper workings and connected to at least one of the shafts. This adit is caved and one of the shafts is open for a depth of more than 100 feet.

Geology.—The property is in a thick mass of fine-grained grey and white limestone of the No. 1 Formation. Production has been of high-grade silver ore, mainly from pods of rusty gossan found near the surface. As presently exposed there is little to indicate the source of the ore. One pit exposes a narrow sheared zone striking north 50 degrees east and dipping 30 degrees to the north along which galena and minor chalcopyrite are scattered in the limestone. One of the dumps contains blocks of vein calcite with clusters of galena and reddish sphalerite. The area is one of thick undergrowth and scattered outcrop.

GLENGARRY

Location.—About one-half mile west of the south end of Loon Lake.

Status.—Crown-granted claim owned by Yale Lead & Zinc Mines Ltd.

Workings.—Caved inclined shaft reported to be 65 feet deep, several trenches, and a shallow adit 650 feet southeast of the shaft. The shaft was made about 1900 and the adit has been driven since 1917.

Geology.—Several short narrow veins on the Glengarry claim in quartzite and hornblende schist contain coarse dark-coloured sphalerite, galena, pyrite, and minor chalcopyrite. The veins in general trend northwest and dip steeply to the southwest. Near the shaft one vein crosses a contact between hornblende schist on the east and micaceous quartzite on the west. In the shaft a vein in quartzite trends northward and dips steeply west. A vein in an open cut 50 to 100 feet northwest of the adit is in hornblende schist. It contains scattered galena in siderite and quartz. In all the veins scattered vugs contain crystals of calcite, quartz, and rarely of sulphides.

GRANT

Location.—South side of Woodbury Creek at an elevation of about 4,600 feet, three-quarters of a mile southwest of the first bridge over Woodbury Creek.

Status.—The property consists of two Crown-granted claims registered in the name of Claude MacDonald, of Kaslo.

Workings.—Several workings are described in the following quotations but only the collar of one of the raises was found when the property was visited in 1963. The property is described in the Annual Report for 1921 as follows (pp. 132–133):—

"The altitude of the lower tunnel is about 4,500 feet. Grey-copper carrying high silver values, with small amounts of galena and zinc-blende, occur in small shoots in quartz-filled fissure-veins which cut a siliceous limestone formation near its contact with the granite. The principal work has been done on a vein cutting vertically across the formation in a north-easterly and south-westerly direction. Access to the vein is by means of two crosscut tunnels about 80 feet vertically apart. The upper crosscut is 28 feet to the vein, which has been drifted on for about 100 feet to the south-west. An ore-shoot encountered in this drift was stoped to the surface. The lower crosscut is 100 feet to the vein, which has been drifted in for about 400 feet to the south-west. Two raises, about 130 and 250 feet distant respectively from the crosscut, are up about 60 feet.

"At the time of the writer's visit in July Bridge & Kennedy were stoping, sorting, and sacking ore from these raises. The width of the vein in these stopes varies from 1 to 2 feet, with a rich pay-streak of quartz and grey-copper from 4 to 8 inches in width. A sample across an 8-inch pay-streak in the stope farthest in from the crosscut gave: Gold, 0.02 oz.; silver, 629.4 oz.; lead, 13.3 per cent; zinc, 4.8 per cent. A sample across a 4-inch pay-streak in an open-cut above the upper tunnel gave: Gold, 0.08 oz.; silver, 851.1 oz.; lead, 35.8 per cent; zinc, 18.6 per cent.

"About 300 feet northerly from the portal of the lower crosscut another vein is exposed in a shallow cut by the side of the trail. This vein, which is about 2 feet wide, apparently has a north-westerly and south-easterly strike, but insufficient work has been done to ascertain the dip. The outcrop of this vein is considerably oxidized from the leaching-out of the sulphides. Some selected specimens of this oxidized outcrop material gave: Gold, 0.01 oz.; silver, 52.1 oz. With the exception of this shallow cut no work has been done on this vein.

"The ore is carefully sorted and Bridge & Kennedy hoped to maintain an average of 600 oz. to the ton for the ore which they were sacking for shipment. Twenty-one tons was shipped to Trail in November."

HIGHLAND

LOCATION.—North side of Cedar Creek one-half to 1 mile west of Kootenay Lake.

STATUS.—The principal claims are the Highland and Josephine Crown-granted claims owned by Western Mines Limited.

WORKINGS.—The principal workings include more than 1,000 feet of drifting and crosscutting on interconnected levels. The portal of No. 7 level, elevation 2,600 feet, is on the north bank of Cedar Creek. In 1963, No. 3, No. 2, and No. 1 levels were open for some distance from the portal, but none of the deeper workings was accessible.

HISTORY.—The Highland was discovered before 1890 and was worked until 1912 by a number of individuals and small companies. Between 1896 and 1900 a mill at the mouth of Cedar Creek and an aerial tram from the mine were constructed. In 1909 the mine was worked in conjunction with the United, 3 miles to the south. In 1912 the Highland was purchased by Cominco Ltd., which operated it fairly continuously until 1926. A new mill and tram-line were built in 1913, and the mill was dismantled in 1952. Between 1947 and 1954 the mine was operated by lessees, principally B. Sterno and E. Meyer, of Ainsworth.

GEOLOGY.—The geology of the Highland vein system is described in Chapter III (*see* p. 46), and because the workings are mainly inaccessible there are no details to be added.

HIGHLANDER

An area surrounding the Highlander mine was mapped in detail between 1951 and 1953 by G. E. P. Eastwood and the results reported in the Annual Reports of the Minister of Mines and Petroleum Resources for 1951, pages 144 to 155; 1952, pages 156 to 162; and 1953, pages 123 to 129. This work was based on a plane-table survey on scales of 200 feet to the inch and greater, made at a time when several of the mines, including the Highlander, were in operation. The study represents a somewhat different point of view from that taken in the present work. Emphasis in Eastwood's work has been on details of lithology and vein characteristics without regard for the regional setting, which at that time was poorly understood. For these reasons Eastwood's work has been put together into one report and on one map and included here almost in the original form.

The properties included are the Albion, Banker, Black Diamond, Highlander, Little Donald, Little Mamie, Little Phil, Maestro, Mile Point, Spokane, Tariff, and Townsite, all of which are Crown-granted claims owned by Yale Lead & Zinc Mines Ltd.

HISTORY.—Development and mining in the area began in 1895 and has been continued intermittently from one property or another by individual owners, small companies, and lessees. Most ore has been produced since 1949, when Yale Lead & Zinc Mines Ltd. gained control of the properties. This company worked principally in the Highlander, Albion, and Banker mines, which became one series of workings with the 2150 level of the Highlander, the main haulage level, until 1954, when the 1900 level collared below the Kaslo–Balfour highway was driven. Although most of the mining and development was done by the company, some was done by lessees, particularly on properties outside of the Highlander mine and between 1958 and 1961 in the Highlander itself.

GEOLOGY.—A compilation of the geological maps published by Eastwood of an area around the Highlander mine, herein called the Highlander area, is shown on Figure 19. It includes the southern end of the first fault slice and the eastern part of the second fault slice between Munn Creek and Loon Lake (*see* Fig. 5). All the mines are in the second fault slice. Within the Highlander area Eastwood mapped 20 rock units in addition to quartz veins, lamprophyre sills, and fine-grained granite, and these are shown in the following table in sequence with the eastern or spatially lowest formations at the bottom and the most westerly formations at the top:—

Unit No.	Description	Thickness (Ft.)
X	Quartz carbonate veins	....
L	Lamprophyre sheets and dykes	....
V	Aplitic granite and quartz monzonite	....
	Intrusive contact	
20	Hornblende schist	....
19	Thin-bedded quartzite, containing thin bands of hornblende schist	130–500
18	Quartzose limestone	0–100
17	Quartz-mica schist	0–130
16	Hornblende schist	250+
15	Thin-bedded quartzite, slightly calcareous in part	0– 50
14	Quartzose limestone	40
13	Carbonaceous limestone	20– 50
12	Quartzose limestone	40
9c	Greywacke tongue	0– 80
11a	Silver schist	30–200
9b	Greywacke tongue	0– 80
11	Silver schist	150–300
9a	Greywacke tongue	0– 60
10	Hornblende schist	110+
9	Greywacke	440–700+
	Disconformity?	
8	Phyllite	0– 10
7	Quartzose limestone	20– 40
6	Phyllite	120
5	Quartzose limestone	30
4	Phyllite	0– 75
3	Quartzose limestone	200–350
2	Platy mica schist	180±
	Contact not exposed	
1	Quartzite and garnetiferous mica schist	100+

Unit 1 is the upper part of the Princess Formation.

Units 3 to 7, inclusive, are the lower Ainsworth limestone, and units 12, 13, 14, and 18 the Banker and Dictator limestone (*see* p. 28). The silver schist and greywacke are included in the fine-grained grey mica schists of this report.

Units 2 to 7 comprise three units of quartzose limestone alternating with four units of very thin-bedded, very fine-grained quartz-poor phyllite, containing common thin beds and lenses of limestone. The limestone is normally medium grained and buff weathering, but coarse-grained white recrystallization lenses are very common. Beds are commonly 6 inches to 2 feet thick. The limestone has been invaded by numerous small blebs of vein quartz, without discernible alteration.

Lenticular greywackes and silver schists which lie west of these six units contain the principal orebodies in the Highlander area. Uniform greywacke of unit 9 is more or less granitized in the lower part and contains innumerable small granite sills and quartz veins in the upper part. Beds range in thickness from half an inch to 6 inches. Hornblende-rich beds are interspersed with mica-rich beds increasingly toward the top of the unit, and the contact with the overlying hornblende schist is gradational. Alternating bands of hornblendic and micaceous material included in granite in the Highlander adit suggest that much of the hornblende schist unit passed southward to greywacke by intertonguing.

The hornblende schist, unit 10, appears to have been a gigantic lens, in part intertonguing with greywacke to the south, and tapering both south and north by gradation into the overlying silver schist. It is normally dark green and rather fine grained, with silky aggregate lustre. Foliation is everywhere pronounced and parallel to bedding in adjoining units but is itself rarely recognizable as bedding. It is warped or crumpled in many places, but definite dragfolding was not observed in it. A 20-foot band of crystalline limestone is intercalated for a short distance. This fourth limestone is cut out by granite in the bluff and grades into silver schist along strike to the northwest, near the second hairpin bend of the road.

The silver schist, unit 11, is characterized by brilliant pearly to pearly-metallic lustre, very thin even lamination, and almost universal cross-crinkles. The characteristic sheen is produced by abundant chlorite and micas, and the colour of the fresh surface ranges from green to brown, depending on the relative proportions of these minerals. Hornblende is present in places and forms lenses, beds, and narrow bands in the upper part of the unit. Quartz predominates at the top. The cross-crinkles are about half an inch wide and range from roughly hemispherical bows in the lamination to definite small dragfolds, generally plunging almost down the dip.

The fifth limestone, units 12 to 14, consists of quartzose limestone, similar to the first three limestones, enclosing a carbonaceous unit (unit 13). The lower contact is exposed only in the Highlander adit, where there is some gradation through hornblendic and quartzose silver schist. Narrow bands or lenses of hornblende schist are scattered through unit 12 south to Loon Creek swamp. The fifth limestone grades to micaceous quartzite (unit 15) upward, and also southward across the swamp. South of the swamp the quartzite grades back to a highly quartzose, micaceous limestone.

The micaceous quartzite is usually strongly banded, fine grained, vitreous, and reddish grey to dark grey in colour. A thin section of a sample taken opposite the Little Mamie adit shows marked graded bedding. Mica increases to the northwest, and the rock grades to a quartz-mica schist.

Hornblende is scattered through parts of the micaceous quartzite, as isolated crystals, and in a few thin bands of hornblende schist. Three of the larger of these bands coalesce near the beginning of the road to Loon Lake, forming another large lens of hornblende schist (unit 16). Quartzite and hornblende schist alternate in the western part of the Highlander adit, and the last 400 feet is driven through predominantly hornblendic material.

Granitic Rocks.—Sills of granite and less quartz monzonite, together with some bodies of completely granitized rock, are abundant. In addition, considerable volumes of the greywacke, especially towards the base, have acquired a texture and composition resembling biotite granite, although bedding remains conspicuous. A small, highly irregular stock intrudes the third limestone in the northern part of the area. Only a very few of the sills exceed 10 feet in thickness. The narrower ones are also short and can rarely be traced from outcrop to outcrop. An exception is a lone sill, intrusive into unit 6, which maintains a thickness of 7 feet for at least 3,500 feet along the highway.

The principal granitic body of the area underlies most of the southern part of the talus slope and bluff south of the lower Banker portal, where it intrudes hornblende schist and the equivalent greywacke and silver schist to the south. Northward it tongues into hornblende schist east of the Banker and Jack Pot workings. It is gneissic almost everywhere and seems to have been emplaced by a combination of forceful intrusion and granitization.

Silver schist has been granitized for a thickness of 50 feet or more next to the hangingwall of the main Highlander-Banker quartz vein, from the road to the south border. The contact with silver schist is gradational over a few feet, but well defined and fairly straight. The rock is characteristically massive, aplitic, and flesh coloured, although iron-oxide stain commonly extends 3 to 4 inches from the weathered surface. To the south it grades to a medium-grained granite. Northward it grades to normal silver schist and a narrow band of silicified rock.

The sills are predominantly medium to fine grained or aplitic, commonly subporphyritic. However, three small sills in the Princess formation are coarsely porphyritic, with somewhat augenized phenocrysts. An outcrop of quartz monzonite, on the west edge of the area, contains large phenocrysts of basic oligoclase, extensively replaced by microcline.

Lamprophyre Sheets.—Eight thin, massive, persistent sheets of mafic rock intrude the Josephine formation, and three of them also cut the main granitic sill. They are cut in turn by quartz veins. Four subsidiary sheets lying close to one or another of the main sheets may be traced for short distances only and are probably offshoots of the respective main sheets. The sheets range in thickness from 1 to 15 feet. Seven are mostly concordant, but the eighth cuts the beds diagonally. Deviations from concordance are normally right-handed jogs in plan and downward crosscutting by steepening of dip in section; left-handed jogs and dips flatter than those of the enclosing rocks are rare. Most sheets are readily recognized by their medium-grey to dark greenish-grey colour. Some are even grained and dioritic-looking, others are diabasic, and yet others are marked in places by nearly spherical aggregates of euhedral epidote crystals. They have been known as lamprophyres since the early days of the camp.

The first sheet intrudes greywacke north of the Highlander–Ainsworth road but does not outcrop south towards the border. It is distinguished from other lamprophyres by large phenocrysts of plagioclase feldspar, rarely of hornblende, and also inclusions of greywacke and granite at many places. Epidote aggregates, commonly with a plagioclase shell, are well developed. Thickness ranges from 6 to 13 feet. A 60-foot right-handed offset occurs at Loon Creek, but the relations are hidden by drift.

The second lamprophyre can be traced with some gaps across the entire length of the area, increasing in thickness from 1 to 12 feet from south to north. It is a little darker than the first sheet and is slightly greenish. It contains small plagioclase phenocrysts almost everywhere, but the groundmass is normally medium grained. The margins are normally chilled, and the narrow south end is entirely aphanitic, although still porphyritic. A subsidiary sheet, 2 feet thick, outcrops about 50 feet stratigraphically above No. 2 for a length of 50 feet near the south border.

A distinctive feature of this sheet is the rather regular occurrence of small, right-handed jogs of about 0 feet every 350 to 400 feet. The precise nature of the jog is obscured by drift in almost all cases, but one jog is fairly well exposed on an old trail at co-ordinates 20,100 north and 14,850 east. The south segment turns abruptly to the northeast, becomes aphanitic, and pinches within a few feet. The north segment is less well exposed but apparently pinches southwest towards the tip of the south segment. This jog is probably controlled by a small northeasterly fracture, pre-lamprophyre in age. Other jogs are probably similarly controlled, although the northeasterly fracture direction can be definitely inferred for only a few. This uniformity is broken by a left-handed jog of 110 feet at 19,100 north. It is possible there are two different lamprophyres here.

The third lamprophyre passes from silver schist to hornblende schist at the second hairpin bend in the road, continues south through the main granitic sill, and disappears in an inaccessible part of the bluff, 700 feet south of the Albion portal. It is uniformly concordant with the country rock foliation, except for one right-handed jog of 20 feet near the south end. The sheet is continuous through the jog as a short northeasterly dyke. The thickness is fairly uniform, ranging between 12 and 15 feet. A subsidiary stringer lies just below it in the Highlander adit. The main sheet is greenish-grey to medium grey in colour, medium grained, and resembles diorite.

The fourth lamprophyre intrudes the hornblende schist of unit 10. It disappears in an inaccessible part of the bluff 300 feet south of Loon Creek ravine, and can be traced north only to the deep draw south of the Jack Pot workings. It is too poorly exposed to show whether any jogs are present. It is about 40 inches thick, fine grained, and grey-black in colour. Quartz blebs occur here and there.

Lamprophyres Nos. 5 and 6 are important because they are associated with mineralized quartz veins and probably contributed to ore localization. No. 5 is in the hangingwall of the Banker orebody, wholly within vein quartz, and No. 6 is 40 feet stratigraphically above, mostly above the quartz vein, but associated with a minor ore lens. One or possibly two subsidiary sheets, 1 to 2 feet in thickness, rake south within the quartz vein 12 feet from the footwall of No. 5; another outcrops for 60 feet north from the road between Nos. 5 and 6.

The fifth and sixth lamprophyres cannot be traced with certainty, and the following description is partly inferred from indirect evidence. No. 5 is apparently continuous from the Banker mine to 500 feet short of the south border; it is interrupted north of the Banker but is present in the Jack Pot. No. 6 diverges westward from the main quartz vein north to the Jack Pot; it is missing for 1,000 feet south of the road then reappears about 100 feet stratigraphically above No. 5 and continues to the Little Mamie shaft, 70 feet from the south border. No. 6 has three small right-handed jogs. No. 5 is 4 feet or less in thickness on surface, but 5 to 8 feet underground; at the south end of the Highlander 2150 level it splits into two strands on opposite walls of the drift. No. 6 is 4 to 6 feet in thickness north of the road and 9 to 12 feet farther south.

The fifth lamprophyre is altered to some extent everywhere but most intensely where closest to the ore zone. It is least altered in the Lower Banker and some of the Highlander 2150 level openings and is a grey to greenish-black medium- to coarse-grained rock. Biotite is prominent everywhere, but feldspar phenocrysts are uncommon, and epidote aggregates are rare. In much of the sheet the groundmass is altered to a dark mat of fine-grained carbonate, serpentine, and chlorite, although biotite and plagioclase phenocrysts are still recognizable. The intensely altered parts of the lamprophyre, as in the Upper Banker and south end of the 2150 level drift, are light grey and clay-like, with characteristic green spots. The clay consists almost entirely of talc and kaolinite. The spots are yellow-green epidote dust on talc. Some greenish spots in less intensely altered material consist of epidote dust on either plagioclase or epidote crystals.

The sixth lamprophyre is for the most part dark grey and fairly fresh and contains plagioclase phenocrysts. Biotite is inconspicuous, although universally present as scattered small flakes. Small epidote aggregates occur in places but are uncommon.

Lamprophyre No. 7 is exposed only near the bend of the road 750 feet southwest of the Upper Banker at the base of unit 13. It is 10 feet thick north of the road, but varies erratically to the south, where it appears to have intruded along two northwesterly fractures for short distances.

The eighth lamprophyre is exposed only in three places underground, striking northwestward and dipping 65 degrees southwest to almost vertical. It is 3 feet thick, medium grained, and dark grey to black where it crosses the Highlander adit. At the south end of the main drift it is only 1 foot thick and is altered to green-spotted grey clay.

Structural Geology.—The major structural feature is a slightly deformed regional dip to the west. Regional schistosity is everywhere parallel to the bedding. In the northern two-thirds of the area the strike is rather uniformly north-northwesterly, ranging between north 10 and 30 degrees west. In the southern third, however, it bends to north, and in the southwestern corner to north 15 degrees east. The structure is further deformed by a series of shallow folds near the Banker workings which plunge southwest at an angle of about 45 degrees and have a wave length of 100 to 250 feet. Comparable broad folds are gentle cross-synclines at the Little Phil and Spokane mines. Regional mapping has shown that these open warps are superimposed on early isoclinal folds which cause much of the lenticular character of the formations. These folds are not well displayed in this area, though one fold hinge in limestone is present near the Townsite mine. Studies in an adjacent area to the southwest (*see* p. 28) and minor structures in the Highlander area indicate that the isoclinal folds plunge somewhat west of north at low angles and have axial planes dipping to the west more or less parallel to the formational dip (*see* Fig. 8).

Minor faulting is prominent throughout the area. Many of the veins follow fault zones and contain or are crossed by faults.

A careful study of faulting in the southwestern part of the area, called the Little Donald area, was made by Eastwood, and although inconclusive in detail (*see* Eastwood, 1953, p. 129) clearly shows the main fault pattern. The faults are shown on the generalized diagram, Figure 20. They are described by Eastwood as follows:—

Most of the faults, both identified and inferred, are referable to four groups, which may have been initiated at somewhat different times. The twelve principal faults in and near the area have been given names or letter designations:—

(1) Bedding shears—faults A to C, possibly the Highlander shear.
(2) Longitudinal faults—Loon Creek and Bench faults.
(3) Diagonal faults—faults D to J.
(4) Water-bearing fractures—sharp, clean breaks, slickensided in part; most are in the Highlander adit.

The relative movement on the bedding shears is unknown. Faults A and B are occupied by the west and east veins respectively of the Black Diamond-Spokane vein system, and C is the shear along which the Little Mamie vein was introduced. It is significant that shear A follows the hangingwall of the hornblende schist band around its drag on the Bench fault. This would tend to suggest that the bedding shears are older than the longitudinal faults and were dragged on them. Possibly the growing shearing stresses were initially relieved in the Little Donald area by

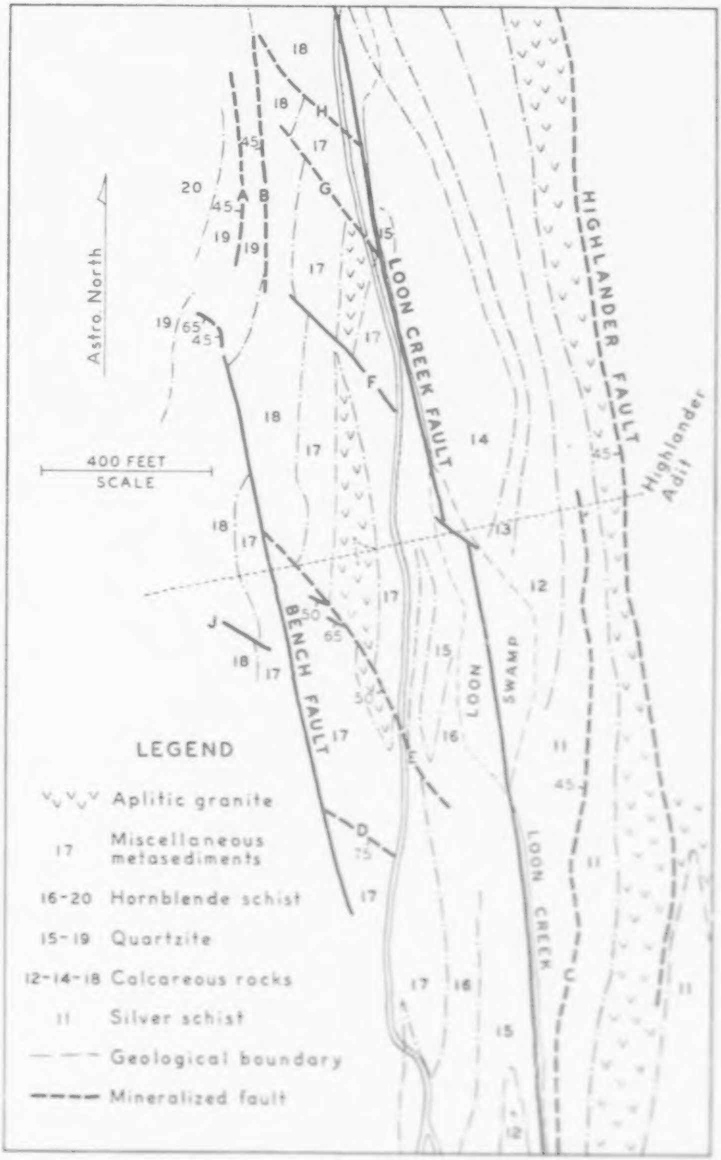

Astro. North
400 FEET
SCALE
LOON CREEK FAULT
HIGHLANDER FAULT
BENCH FAULT
Highlander Adit
LOON SWAMP
LOON CREEK
A
B
D
E
F
G
H
J
LEGEND
Aplitic granite
17 Miscellaneous metasediments
16-20 Hornblende schist
15-19 Quartzite
12-14-18 Calcareous rocks
11 Silver schist
Geological boundary
Mineralized fault

Figure 20. Structural plan of the Little Donald area.

movement along certain of the weakest bedding planes. The carbonaceous, quartzose limestone in unit 18 and the contact between the strong, tough hornblende schist and the brittle quartzite might be expected to be especially weak.

The dip of the longitudinal faults is unknown, and the amount of displacement on the Loon Creek fault is uncertain. The strikes of these two faults are markedly parallel. Over most of the area they strike about 15 degrees to the left of the bedding, but north of the area the bedding swings to parallelism. The Bench fault is named from its occurrence along a marked topographic bench, at about 3,000 feet elevations, which extends from the Black Diamond surface showings to the south end of the area. The fault trace apparently climbs northward to a shallow draw behind a shoulder of resistant rocks overlooking the Little Phil. It is nowhere exposed, but is evidenced by the right-hand displacement of unit 18 and by a profusion of strike-slip dragfolds in the outcrop 400 feet southwest of the Black Diamond portal. It has not been positively identified in the Highlander adit. The Loon Creek fault follows a shallow trench, which is occupied by Loon Creek and Loon Swamp through the Little Donald area and south to Loon Lake. Northward the trench extends at least to Munn Creek, and southward this lineament is marked by the straight western shore of Loon Lake. The fault is evidenced by a profusion of right-hand strike-slip dragfolds opposite the former Black Diamond dump and immediately west of Loon Swamp and by a marked curvature of bedding into the west side of it at several places.

The diagonal faults are so named because their traces are diagonal to the block between the longitudinal faults. Fault D dips 75 degrees southwest and is occupied by the Little Donald south vein. The direction and amount of movement are unknown, but the dislocation appears to be slight. Fault E dips 50 degrees southwest and contains the Little Donald main vein. It has at least three offshoots striking west-northwest and dipping steeply south; its displacement is not definitely known but appears to have a left-hand horizontal component. It is not clear whether fault E dies out east of the Bench fault, or whether one fault is displaced on the other. It cannot be identified in the Highlander adit. Fault F is not exposed, but is inferred from the observed right-hand displacement of silver schist and white dolomite. It does not reach shear A and may not cross shear B. Fault G is exposed as a sharp galena-bearing fracture in the cut of a path up to the Black Diamond portal. Greywacke and white dolomite appear to have been displaced by it to the right. Fault H is exposed in the Little Phil adit as a wide zone of brecciation, shearing, and general softening of the rock, containing pockets and lenses of ore minerals. The absence of the white dolomite from and the presence of an abnormally thick section of carbonaceous limestone in the adit are taken to indicate considerable left-hand displacement on this fault. A slight offset of the main lower drift at a short lagged section suggests that this fault may pass a few feet in front of the Little Phil upper portal and extend to shear A. No evidence of it can be seen near shear A on surface. Fault J is postulated to account for a small right-hand jog in exposures of the white dolomite west of the Bench fault.

The water-bearing fractures mostly strike parallel to the bedding, but some strike as much as 45 degrees to the right or left. The dip is usually more than 50 degrees, northwest to southwest. None show evidence of the amount of movement, and only two show clear indications of the direction of movement. One of these is a northwest striking fracture 190 feet east of the dam in the Highlander adit, displaying slickensides that rake southeast, and indicate that the footwall (northeast side) moved up and northwest. The other is a northeast-striking fracture 220 feet west of the dam, where a contact between hornblende schist and quartzite has been displaced an unknown distance to the right.

MINERAL DEPOSITS.—The principal veins in the area are:—

(1) Highlander (which outcrops on the Highlander, Banker, Albion, and Jack Pot claims).
(2) Black Diamond-Spokane (which outcrops on the Little Donald, Black Diamond, Little Phil, Maestro, Korea, Spokane, and Trinket claims).
(3) Little Donald.
(4) Townsite.

(5) Little Mamie.
(6) Tariff.
(7) Mile Point.

Highlander.—This quartz-carbonate vein has produced most of the ore mined in the area. It is parallel to the foliation, striking north and dipping to the west and has been traced for about 5,000 feet on strike and worked for about 1,300 feet down the dip. Ore is everywhere restricted to the vicinity of a shear and a lamprophyre sill. Details of the vein are diagrammed on Figure 21.

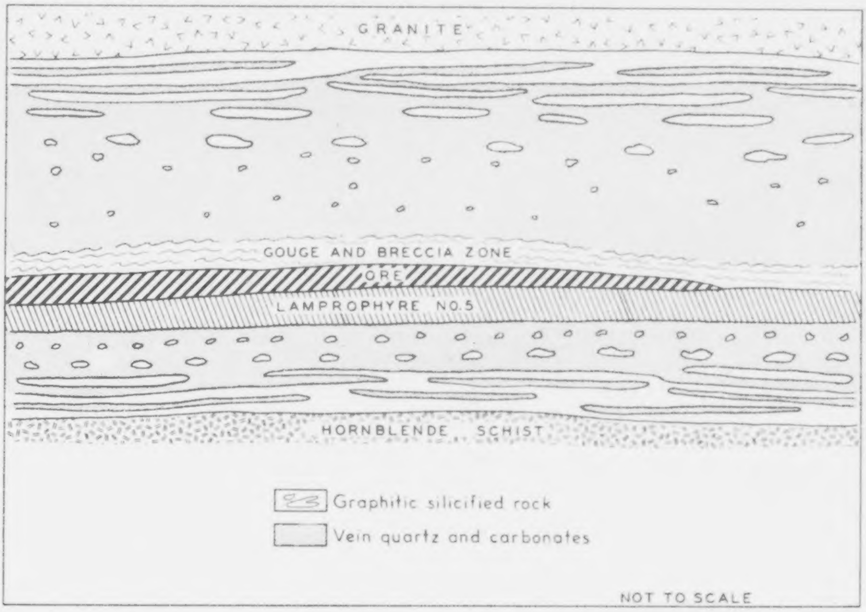


Figure 21. Sketch of the Highlander vein on surface above Albion adit.

The wallrocks vary from place to place as a result of facies changes and granite emplacement. They are silver schist north of the Banker, but the hangingwall rock is granitized silver schist to the south, and the footwall rock is hornblende schist from the lower Banker south to the Highlander adit, granite for a further 900 feet, and silicified silver schist farther south. The vein has engulfed the fifth lamprophyre, probably by ingress along the same fracture.

Black Diamond-Spokane Vein.—The Black Diamond-Spokane, like the Highlander vein, is parallel to the foliation but also has associated short northwestern-trending cross-veins. It consists of two subparallel parts called the east and the west veins. The west vein is the most persistent and has been the most productive. The principal drifts and crosscuts are shown on Figure 19. On the Spokane claim the east vein and the cross-veins have been opened by pits, trenches, and at least two inclined shafts. The west vein has been opened by four adits, designated S1 to S4 on Figure 19, and by many surface workings.

The east vein is sparsely mineralized in the Black Diamond and Little Phil, but is reported to have yielded some ore in the Maestro. A drift, now caved, followed it for some distance in the Black Diamond. Some ore was apparently mined from the east vein on the Spokane claim.

The west vein contains at least three orebodies in addition to small lenses of ore minerals and a general sparse mineralization. The largest orebody on the Black Diamond is shaped roughly like the blade of a table knife, bent around a cross-warp and raking gently north into the Maestro. It is about 150 feet deep and has been opened for a length of 1,400 feet. The lower edge is somewhat irregular, raking down from surface above the middle of the Black Diamond drift to the Little Phil lower adit, then rising above the Little Phil lower drift and entering the north end of the Maestro drift. The upper edge of the orebody appears to pass through surface a short distance north of the upper Maestro adit; its outline is unknown. On surface on the Spokane claim a narrow band of galena and sphalerite, 6 to 18 inches wide, is almost continuously exposed in the west shear for 850 feet north from the two cross-veins to 400 feet south of Munn Creek. It seems probable that this is a single orebody, although there are lean to barren stretches in the third and fourth adits. In the second adit the shear contains only a narrow quartz vein and very sparse pyrite, with no ore minerals; this adit is probably above or north of the orebody.

A gouge and breccia band along the west vein is 2 to 4 feet wide on surface, but varies considerably in width underground. It is 20 feet wide at the Black Diamond and lower Little Phil adits, but narrows to 2 or 3 feet at the faces of the respective drifts. The most intense shearing is against the relatively solid quartzite hangingwall, decreasing through a zone of brecciation to the hornblende schist footwall. The gouged and brecciated quartzite is much darkened by carbonaceous material. Veins, veinlets, and blebs of both white and yellow carbonate, and less quartz, are profusely distributed and have variable attitudes. The larger and more continuous veins are nearly all bedded and are composed largely of yellow carbonate, probably siderite. The veins are all rather small in the Black Diamond drift and in the south part of the Little Phil lower drift, but increase in size and continuity in the north part. Galena and sphalerite occur largely in and beside the larger veins of yellow carbonate and hence are more abundant in the north drift.

Three northwesterly trending cross-faults make ore where they cross or join the bedded veins. The main oreshoot of this type is on the Black Diamond. It is a small chimney at the intersection of a cross-fault and the west vein with ore extending a few tens of feet each way on both structures. The cross-fault strikes north 60 degrees west and dips 60 degrees to the southwest and is followed by a drift in the south end of the Black Diamond mine. It has displaced the east vein about 4 feet to the left and appears to feather out to the southeast. On surface it curves southward into the foliation and high-grade galena has formed in the angle of this curve.

Two comparable cross-veins make small pods of ore where they intersect the west vein at the south end of the Spokane claim. They are about 30 feet apart, strike north 50 degrees west, and dip 40 to 50 degrees southwest. The southwesterly of the pair has displaced the west vein about 15 feet to the right and the east vein about 4 feet right. Displacement on the northeast fault appears to be only a few inches. The southwest fault is mainly a 3-foot band of brecciated and altered quartzite, containing highly schistose material and some lenses of vein quartz. Some galena and sphalerite occur along the contacts of the quartz lenses. The northeast fault is a narrow band of gouge and schistose material, bounded by a tight hangingwall but grading to a brecciated footwall zone. This brecciated zone contains pods of vein quartz and carbonates, and disseminated galena over a width of 1 to 3 feet.

Little Donald Veins. — The Little Donald veins consist of galena-sphalerite mineralization along faults D and E and their offshoots shown on Figure 20. A trench in fault D exposes about 3 inches of nearly massive lead-zinc sulphide in the hangingwall, but in the adit there is only very sparse mineralization in quartz and carbonates. The fault appears to constrict westward through the outcrop, but a more northerly striking offshoot contains 3 to 4 inches of massive galena where it traverses the outcrop. Aplitic granite is strongly sheared and contains disseminated sphalerite and galena for about 3 feet on either side of fault E. Only a short section of this mineralized part is now exposed. The presumed southeasterly continuation of the fault is filled with barren white vein quartz. Three west-northwest striking offshoots have been exposed. A short adit has been driven on the most southerly offshoot, but it contains only 2 feet of vein quartz and altered granite, without visible mineralization. The middle offshoot was apparently followed by drifting from the fault; any mineralization is now hidden by caving. The north offshoot is exposed in a trench as 2 feet of vein quartz and carbonate with sparse galena.

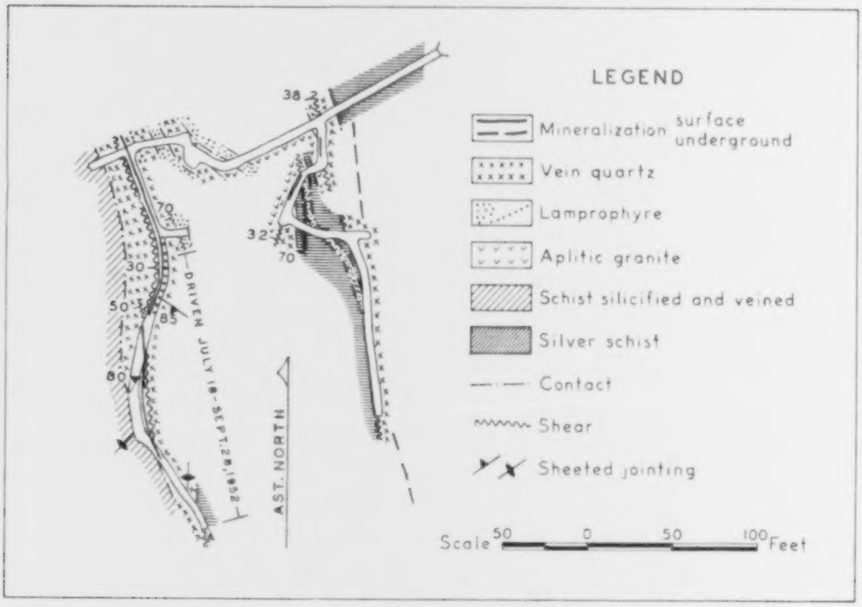

38
70
32
70
30
50
85
80
DRIVEN JULY 18-SEPT.28,1932
AST. NORTH
LEGEND
Mineralization surface
underground
Vein quartz
Lamprophyre
Aplitic granite
Schist silicified and veined
Silver schist
Contact
Shear
Sheeted jointing
Scale 50 0 50 100 Feet

Figure 22. Geological map of the Townsite mine.

Townsite Veins.—Mineralization in and near the Townsite mine occurs in complex association with small lamprophyre dykes, large quartz veins, subparallel shears, and sheeted jointing. Surface exposures suggest a fairly continuous mineralized shear extending about 600 feet along the silver schist-greywacke contact from south of the Spokane road nearly to Munn Creek, but underground the relations are much more complex (*see* Fig. 22). A small mass of white aplitic granite occurs in the upper part of the silver schist and may be an extension of a larger mass to the south. It closely resembles aplitic granite in the hangingwall of the Highlander vein that is believed to have formed by complete granitization of silver schist. Vein quartz and lamprophyre cut schist and aplitic granite and are in turn cut by shears and are locally mineralized, but their relative ages are uncertain. General relations suggest that lamprophyre has intruded quartz, but quartz veinlets cut the dykes.

The quartz seems to be in two distinct but rather irregular veins, roughly following bedding in the schists, and separated by granite and silver schist. The veins consist mostly of coarse-grained quartz, with some carbonates and scattered dark fragments. These fragments are equidimensional and unaligned, and suggest inclusions of granite or of silicified schist into which carbon has been introduced. The marginal parts of the veins are sheeted with tabular inclusions of aplitic granite and silicified schist, and grade into quartz veinlets cutting granite and schist at a slight angle to the foliation. The schist in the hangingwall of the west quartz vein has been extensively silicified.

Lamprophyre is present as a swarm of small discontinuous dykes, all dipping west, but commonly at an angle different from the dip of foliation in granite and silver schist. In plan the dykes are somewhat sinuous, alternately following and angling across the strike of foliation. Near Munn Creek two larger sheets emerge from the swarm and appear to follow the foliation northward. There is no clear relation between the dykes and either shearing or mineralization

The shears are marked by gouge and breccia bands up to 3 feet thick, all west-dipping, but varying considerably in attitude. The thicker and longer bands are shown in Figure 22. The north shear in the west drift dips less steeply than the south shear, but has steep branches. Two small shears, not shown, in the short crosscut from the west drift, dip 10 degrees. A radial pattern of shears in the east drift conforms roughly to the angle between the aplitic granite body and the east quartz vein. There is no definite evidence for displacement on any of the shears, even where two are in contact as in the west drift, but it is possible that shearing is responsible for complications in the lithological pattern.

Sheeted jointing is conspicuous in isolated parts of the quartz vein along the west drift. The fractures are strictly parallel, 2 to 6 inches apart, separated by rather crumbly quartz.

Galena-sphalerite mineralization occurs in the following associations:—

(1) In the footwall of a lamprophyre dyke, 30 feet east of the west drift; it is sparse.

(2) In a shear along the contact between granite and vein quartz. The two occurrences in the east drift are of this type, and are sparse.

(3) Along the footwall of a shear in vein quartz, in part in the hangingwall of a small lamprophyre, in the north half of the west drift.

(4) Along the hangingwall of a shear in vein quartz and concentrated at intersections with sheeted jointing, in the south half of the west drift.

The third association resembles the type most commonly seen in the Highlander mine. Samples were taken from the north wall of the adit, from 11 feet south, and from 62 feet south. Together they illustrate the average grade of this length of vein.

Sample No.	Location	Width	Gold	Silver	Lead	Zinc
	Ft. South	In.	Oz. per Ton	Oz. per Ton	Per Cent	Per Cent
1	0	27	*Nil*	Trace	0.1	1.6
2	11	5½	*Nil*	7.7	48.1	4.4
3	62	6	*Nil*	0.5	0.2	17.7

The fourth association includes two pockets of abundant sphalerite and traces of galena extending back along sheeted jointing from the hangingwall of the shear. Two other pockets of sheeted jointing in the shear footwall are but sparsely mineralized.

No definite correlation can be made between the mineralized shear on surface and any of the shears underground. The surface shear resembles the shear in the north half of the west drift, but its downward projection at 30 degrees places it midway between the drifts. It is traceable with assurance from south of the Spokane road to a short inclined shaft northwest of the main adit, but northward its extension is indefinite. It is represented by 2 to 3 feet of gouge and brecciated vein quartz with some carbonaceous material, containing a few inches of galena and sphalerite along the footwall. Sparse mineralization extends about a foot into a lamprophyre that forms the footwall north to the shaft. Two samples were taken in sequence across the mineralization in the north wall of the shaft:—

Sample No.	Description	Width	Gold	Silver	Lead	Zinc
		In.	Oz. per Ton	Oz. per Ton	Per Cent	Per Cent
1	Shear footwall	2½	Trace	3.16	23.2	5.6
2	Lamprophyre	9½	*Nil*	0.3	0.3	0.7

Farther north a short adit has been driven on a pair of narrow curving shears in vein quartz, which are sparsely mineralized. Some sheeted jointing in vein quartz near Munn Creek is not mineralized.

Traces of copper, cadmium, and tin were found spectrochemically in most of the samples from the Townsite area.

Little Mamie Vein.—A thin cavernous quartz vein persists along the footwall of No. 6 lamprophyre for 2,300 feet north from the south border. It is trenched at intervals but appears to have yielded ore only in the southern 450 feet. These openings are now caved and could not be examined. Farther north the vein contains abundant druses of quartz crystals with some pyrite. Ore mineralization is very lean at surface, but intersections of as much as 2 feet of 30 per cent combined galena and sphalerite were obtained in drill cores 200 feet lower.

In the Highlander 2150 adit there is no definite quartz vein, but instead a succession of gouge and breccia bands below the lamprophyre. Siderite and appreciable amounts of galena have been introduced between the first pair of gouge bands below the lamprophyre, and a small stope was driven from the adit. Some galena and sphalerite also occur as veinlets in the lamprophyre.

Vein quartz intersected by drilling west of the Mohr shaft, in the hangingwall of No. 6 lamprophyre, contained about 3 feet of 60 per cent galena and less sphalerite; the lamprophyre contacts are barren farther north. This ore is probably a direct offshoot of the Banker vein, rather than an extension of the Little Mamie vein.

Tariff Vein.—The Tariff workings are now caved, and the long drift on what is presumably the downward continuation of the vein in the Highlander adit is dammed at 60 feet. Poor surface exposures indicate that mineralized vein quartz extends 1,100 feet north from the south border of the map, Figure 19.

The vein is in greywacke near many small granitic sills, and in the Highlander adit it follows a chloritic shear. The vein dips 25 degrees west in the adit but steepens to 50 degrees farther south. The vein consists of quartz, calcite, and siderite, with a little galena and sphalerite.

JEWEL

Location.—South of Cedar Creek about 1,000 feet west of Kootenay Lake.

Status.—Crown-granted claim owned by Yale Lead & Zinc Mines Ltd.

Geology and Workings.—The main showing on the Jewel claim is a galena-bearing vein of calcite and siderite in grey fine-grained mica schist, calcareous mica schist with grey marble lenses. The vein strikes north 60 to 70 degrees west and dips 70 degrees to the south and is about 3 feet thick at the widest place. It has been followed for about 200 feet in an adit from which small amounts of ore have been mined. Near the face of the adit the vein curves northward into the foliation. Other similar veins are reported from the shore cliff on Kootenay Lake east of this vein, but were not seen by the writer.

KOOTENAY FLORENCE

The Kootenay Florence property is one of the largest in the Ainsworth camp. It is the principal mine included in a group of Crown-granted claims owned by Western Mines Limited. The main workings are on the Florence vein, which outcrops at several places a few hundred feet north of Princess Creek and is the major part of the Florence vein system (*see* p. 42). The property also includes a number of mineralized fractures and associated replacement bodies known as the Lakeshore section and lying south of the Florence vein.

WORKINGS AND HISTORY.—The Florence vein has been mined from nine levels. The portal of No. 9 level, the main haulage, is just south of the Florence townsite at an elevation of 1,942 feet. No. 1 level is a short drift on the vein at an elevation of about 2,750 feet, 3,500 feet northwest of the townsite. An outline of the principal workings is shown on Figure 23.

The original Florence group was explored in the 1890's, but serious development began in 1916. In that year Florence Silver Mining Company Limited built a 150-ton mill, tram-line, and power plant and did 2,000 feet of tunnelling. The mill was in operation in 1917, and the rate of mining in 1918 and 1919 was the highest in the history of the mine. Production in 1920 was about 1,200 tons, and in 1921 some 500 tons of selected ore was shipped to the smelter. At that time it was reported that " large bodies " of milling ore were developed, but that the grade was too low at current prices. During the succeeding two years, ore was milled as mined, partly on a leasing basis.

Late in 1926 Kootenay Florence Mining Company Limited, a Stobie Forlong-sponsored company, acquired the property, and by the end of 1927 had driven No. 9 adit a distance of 2,000 feet. No. 9 level was driven a total distance of nearly 8,000 feet by the end of 1929, when all operations ceased. During this stage of development the Lakeshore and Nicolet-Snelling groups were added to the Florence group. Drifting was done on the Florence vein on No. 9 and No. 8 levels, and exploration was done on what was believed to be the downward extension of the Lakeshore vein south of the Florence. No ore was mined, except 41 tons of uncertain derivation. Late in 1942 Wartime Metals Corporation came into control of the mine and started immediately to bring it into production. The mill was completely remodelled and was in operation June 30, 1943, on jig tailings dredged from the lake. A raise was driven from No. 9 to No. 5 level, and No. 5 level was rehabilitated from the portal to a point from which a crosscut was driven to the top of the raise. Work stopped May 16, 1944.

In 1945 Ainsmore Consolidated Mines Limited bought the mill and optioned the Kootenay Florence property. Some 1,500 tons of ore left broken in the stopes was milled on a contract basis for the owner, George Webster, of Toronto, and some development work was done. The property was bought at the end of 1946 and merged with the Spokane group and other claims to form an extensive holding. Under the management of Carl Mohr the mill was operated for the most part on a one- to two-shifts-per-day basis. A little work was first done on Nos. 7 and 8 levels in addition to No. 9, and later production came from a winze with two sub-levels 50 and 105 feet on the slope below No. 9 level. The winze is reported to have caved in 1947.

W. J. Bull assumed charge following Mr. Mohr's death in the autumn of 1947, and drove a raise on a vein fissure east of the main raise; this section provided most of the ore mined in succeeding years. When the present company bought the property in the summer of 1951, Mr. Bull was retained as manager, and production continued until 1953.

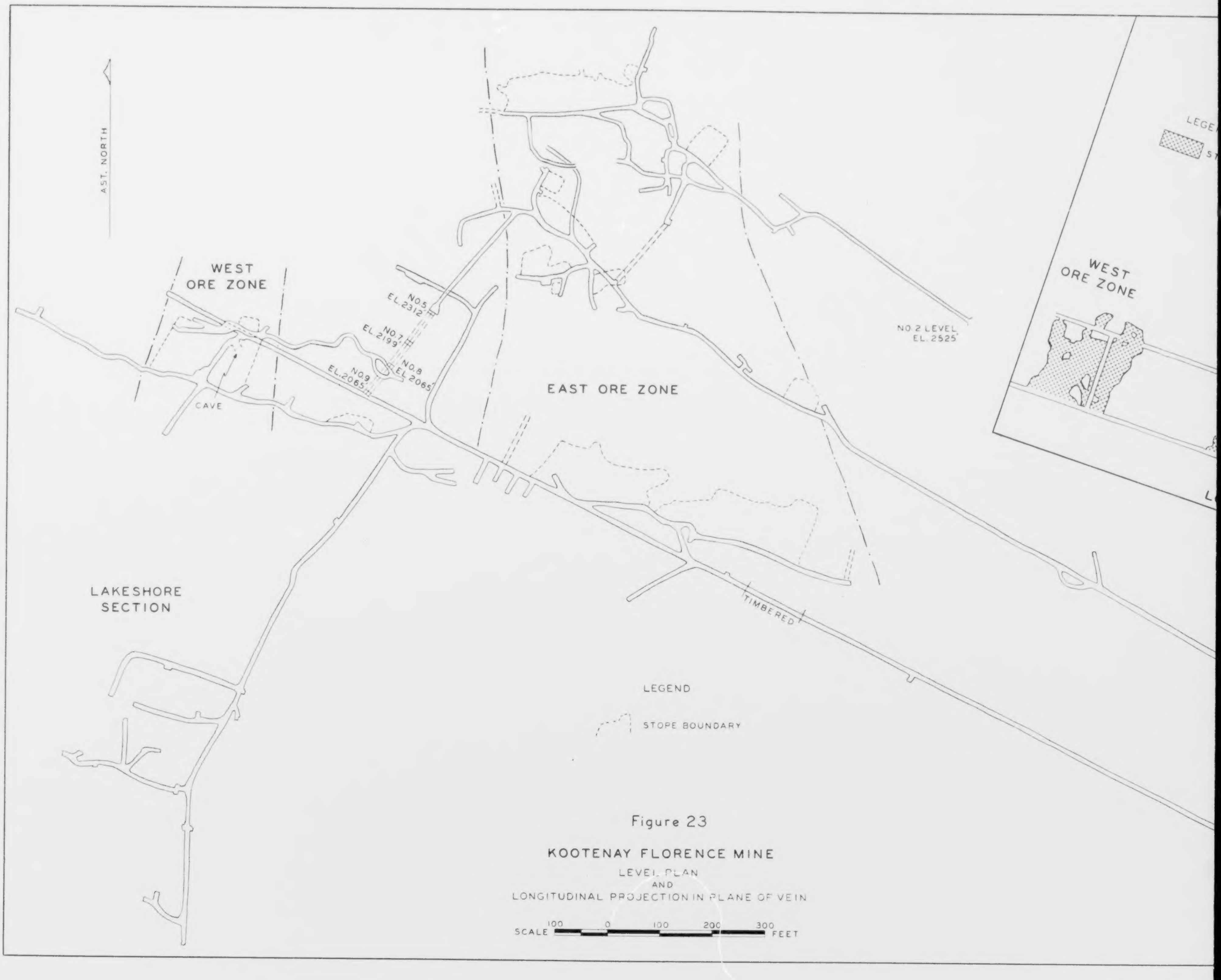
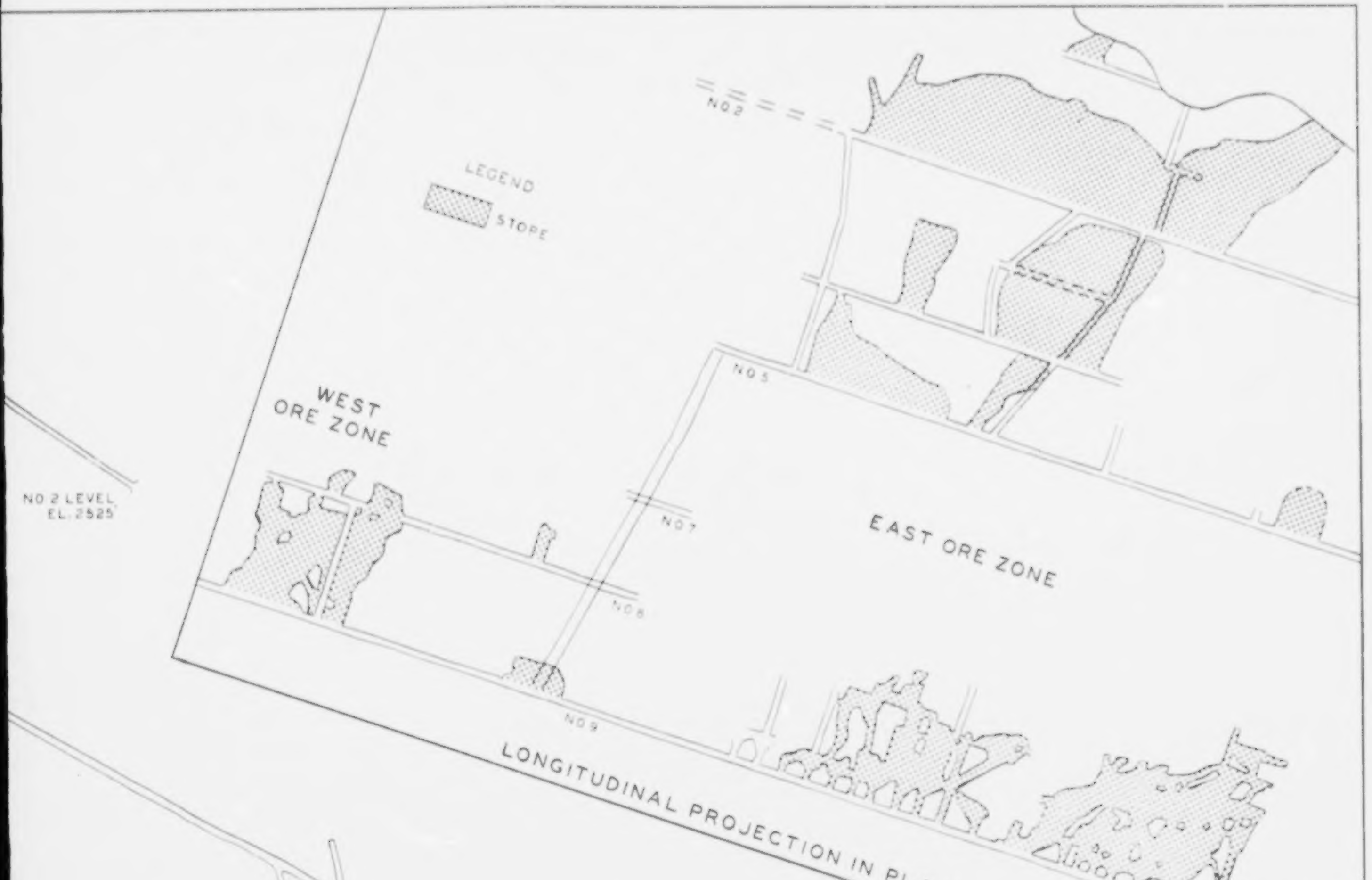

AST. NORTH
WEST ORE ZONE
NO.5 EL.2312
NO.7 EL.2199
NO.8 EL.2065
NO.9 EL.2065
CAVE
EAST ORE ZONE
NO.2 LEVEL, EL.2525
TIMBERED
LAKESHORE SECTION
LEGEND
STOPE BOUNDARY
LEGE
ST
WEST ORE ZONE
L
SCALE 100 0 100 200 300 FEET

Figure 23

KOOTENAY FLORENCE MINE

LEVEL PLAN
AND
LONGITUDINAL PROJECTION IN PLANE OF VEIN


NO 2
LEGEND
STOPE
WEST ORE ZONE
NO 5
NO 7
EAST ORE ZONE
NO 8
NO 9
LONGITUDINAL PROJECTION IN PLANE OF VEIN
NO 2 LEVEL, EL. 2525'
NO.5 LEV'L EL. 2296'
NO 9 LEVEL, EL. 1942'
1000' TO PORTAL

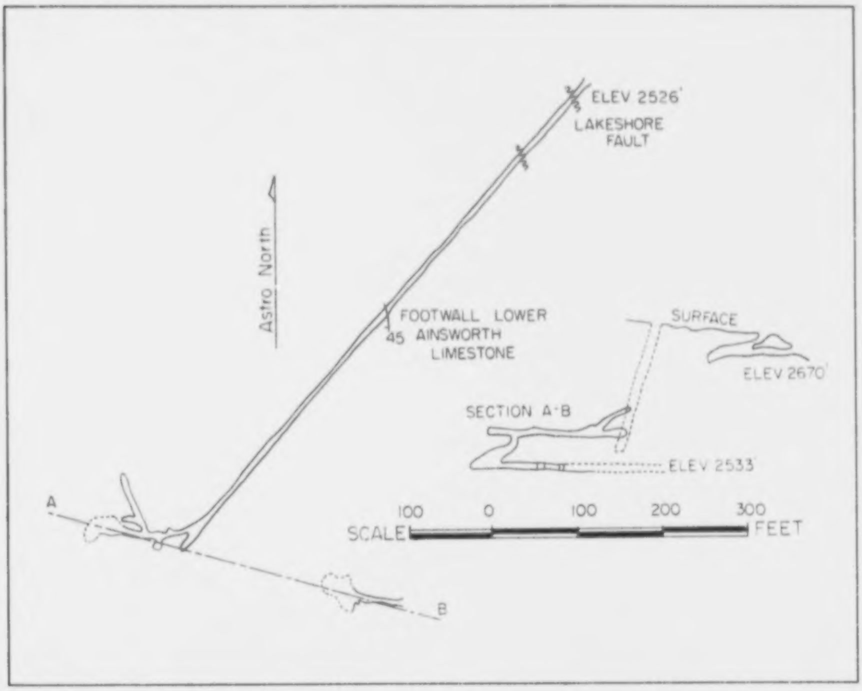


Figure 24. Lakeshore mine, level plan and longitudinal section.

In 1954 Cominco Ltd. made an agreement for eventual control of the property. Geological and geophysical surveys were done in 1954 followed in 1956 and 1957 by diamond drilling totalling 23,000 feet, mainly from surface. This work was designed to test for replacement ore in limestones like that at the Bluebell, and initial results were encouraging, directing attention to the Lakeshore section.

The Lakeshore workings are mainly on the Carey Fractional Crown-granted claim a few hundred feet south of Princess Creek one-quarter to one-half mile southwest of the Florence townsite. The workings are shown on Figure 24 and their relation to the Kootenay Florence workings on Figure 3. The early work on the Lakeshore mine was done between 1916 and 1928, and the property gained its name from the Lakeshore Mining Company, of Spokane, which owned it between 1921 and 1923. In 1957 Cominco Ltd. extended the lower Lakeshore adit by a total of 750 feet of drifts, crosscuts, and raises and drilled eight holes totalling 1,400 feet from underground. This work exposed fractures in limestone adjacent to which there is a limited amount of replacement mineralization. Some of this mineralization was mined by lessees in 1958 and 1959, and no work has been done since then.

GEOLOGY.—The general characteristics of the Kootenay Florence vein and the mineralized fractures on the Lakeshore property are described in Chapter III (p. 49) as part of the Florence vein system. Very little of the Kootenay Florence and Lakeshore mines were accessible while the present study was in progress. The following notes on the Kootenay Florence are based on a report by M. S. Hedley (Ann. Rept., 1951, pp. 157–159) and on the Lakeshore by geologists of Cominco Ltd.

Regarding the Kootenay Florence, Hedley writes:—

The ore occurs in a vein zone striking about north 70 degrees west and dipping on the average 45 degrees to the south. The vein crosses schists and some bands of limestone dipping to the west at angles between 20 and 40 degrees as a rule. Old reports referring to the upper workings, above No. 5 level, mention the occurrence of ore replacing limestone, but current workings below No. 5 level show that almost all the ore occurs as a fissure filling and is not restricted to limestone. A newly opened stope section on No. 9 level shows galena and sphalerite in green, silicified, and chloritic rock beyond the limits of the vein fissure in a replacement-alteration zone that is not known to be restricted to limestone.

The mine is opened by No. 9 adit level, elevation 1,942 feet, driven 3,800 feet along the general strike of the vein; the vein is not seen in the outer 2,400 feet. No. 5 adit, 350 feet above No. 9, encounters the vein about 1,200 feet from the portal. No. 2 adit, elevation 2,525 feet, apparently contained most of the stoping ground of the old mine. Figure 12 shows the levels and a longitudinal projection. The ore zone on No. 2 level is inaccessible, and the inner part of No. 5 is open only to a crosscut to the top of the raise from No. 9 level. Information regarding stopes above No. 5 level is taken from old maps and may or may not be complete. Nos. 3 and 4 levels are omitted for clarity. No. 8 level was driven from a vertical raise 3,680 feet from the portal of No. 9, and No. 7 level, omitted for clarity, was driven from a raise extending from No. 9 to No. 5. Workings 600 to 1,000 feet southwest of the main course of No. 9 level are believed to be on the downward continuation of the Lakeshore vein, exposed at the surface. A winze 100 feet below No. 9 in the west ore zone is not shown.

Two ore zones are indicated by the present extent of the workings—an eastern zone 450 to 700 feet long and a western zone 200 to 250 feet long. The boundaries of these zones are poorly defined, and future work may prove the concept of two zones to be wrong; the vein is known to be mineralized between the zones but so far has not produced ore.

Mining is made difficult by bad air and bad ground. The air in unventilated workings is deficient in oxygen, a result apparently of strong oxidation. In 1951 none of the workings west of the east ore zone could be entered and the raise to No. 5 level had caved, completely cutting off natural ventilation. The bad ground is a result of slaking and swelling of some limestone and limy schist, a condition exaggerated by dampness. The final product is a sort of plastic mud in which it is very difficult to maintain openings. The ground is particularly bad in the general vicinity of a natural cave in the footwall of the vein on No. 9 level and extends up the general course of the vein to the east, caves having been encountered on No. 7 level and possibly in the older workings on No. 5 level. The cave zone is a locus of higher temperatures. When encountered, the cave was full of hot water, and many exceptionally fine crystals of green fluorspar were recovered from it.

The pattern of workings in Nos. 2 and 5 levels, together with the report of replacement ore, suggests that ore formed along the bedding in a northerly direction, presumably in bands of limestone. On the same levels, ore was stoped on vein branches striking northwest and east-west.

The west ore zone is on an east-west section of vein, and the eastern ore zone on No. 9 level, although continuous, shows northwest and east-west stretches of vein. The east orebody is on a footwall part of the lode—the hangingwall branch may cross the main part of the adit in a heavily timbered section to join the footwall branch east of the east orebody.

It appears that, in the region of the present mine workings, the vein does not occupy a single fissure but rather a fissure zone. Figure 9 illustrates what is known and inferred of the main elements of this fissure zone. It is obvious on the lower levels and inferred on the upper levels that the two known ore zones are localized on two " eyed " sections of the vein fissure, involving a jog to the left in each case. It follows that if the displacement on the vein fissure was of hangingwall to the east then the east-west branches are tensional in origin and would theoretically favour ore deposition.

The ore occurs in widths up to 15 feet. The gangue includes rock, calcite, quartz, pyrite, pyrrhotite, chalcopyrite, and fluorite. Galena and sphalerite occur in pods and lenses, or more or less evenly distributed through the vein. The walls of the east ore zone are locally sheeted and locally soft and swelling, so that care must be taken not to overlook ore in the walls and also to provide adequate support. Mining has been by open stoping.

On the Lakeshore property, mineralization can be seen in both the upper and lower workings and its extent can be deduced from the diamond drilling. Above the upper Lakeshore adit in the back of a stope just below surface, several fractures contain sulphides. The fractures strike north 70 to 80 degrees west and dip steeply south or are vertical. The 8 or 10 fractures exposed each contain less than an inch of sulphides, but, judging from the shape of the stope and remnants of ore on the walls, sulphides spread out from the fractures to form an orebody up to 10 feet thick and 40 to 60 feet in strike and dip length. This mineralized zone is near the centre of the lower Ainsworth limestone. Two other stopes of comparable size and shape have been mined on the same set of fractures and in the same " stratigraphic " position in the limestone in the lower levels of the mine. Limestone beneath these stopes is decomposed and oxidized.

Five groups of mineralized fractures are exposed on surface between the Nicolet (*see* p. 102) workings about 1,500 feet south of the upper Lakeshore and the portal of the lower Lakeshore adit. They strike between north 65 and north 75 degrees west and dip steeply to the south.

The area was drilled in detail by Cominco Ltd. 300 feet north and 400 feet south from the upper Lakeshore workings, and the drilling extended as much as 700 feet down the dip of the lower Ainsworth limestone. More widely spaced holes were drilled to the north and to the south and some holes penetrated the upper Ainsworth limestone. The holes were drilled on sections running north 62 degrees east, and the ore intersections which occurred regularly in the early drilling were thought to represent sheet-like replacement bodies lying parallel to the foliation. Underground work in the lower Lakeshore exposed two of the best intersections and showed that although replacement ore was present, it was confined to within a few feet of steeply dipping fractures more or less parallel to those exposed in the other workings and on surface.

Stoping on one of these orebodies in 1959 produced 720 tons with an average grade based on production statistics of: Silver, 1.6 ounces per ton; lead, 3.2 per cent; and zinc, 4.5 per cent.

The drill results and underground exposures suggest that in this area there are four or five groups of mineralized fractures and two important stratigraphic layers favourable for replacement. One is at the hangingwall of the lower Ainsworth limestone and the other is somewhat above the centre of the limestone. Replacement extends a few feet laterally from a fracture or a group of closely spaced fractures, and orebodies have a maximum strike length of 15 to 20 feet. They probably are no more than 5 feet thick and have a long dimension plunging at about 20 degrees to the west parallel to the line of intersection of the fractures and the replaced layer. This dimension is not known, but judging from the zone that has been mined may be several hundred feet and will include irregular more or less barren stretches.

Suggestions that replacement is affected by folding, and that the fracture system is associated with a local broad arching of the formations, have not found support in the present study. Isoclinal folds on axes that plunge gently to the north and with axial planes dipping to the west are present in the area. In the Kootenay Florence mine, the lower and upper Ainsworth limestones converge in depth, and the upper Ainsworth pinches out upward (*see* p. 25). Also a layer of hornblende schist found at the face of the deepest crosscut (No. 9 level) is not found on surface up the dip. The details of folding are not known, but these relationships and many north-plunging lineations and minor folds suggest the presence of isoclinal folds. The pattern of the folding is probably like that found in the same fault slice 5 miles to the south near the Krao mine (*see* p. 28). This folding controls the distribution of the limestones which indirectly affects mineralization, but so far no mineralized zones associated with gently north-plunging isoclinal folds are known.

A broad arch on the Lakeshore and Kootenay Florence properties plunges westward and is outlined by a change in the formational strike. Stereographic plots of the attitudes of the limbs of the arch suggest that the zone of maximum curvature plunges about north 55 degrees west at 20 to 30 degrees and the axial plane dips steeply to the north. The strike of the Florence vein system is close to the zone of maximum curvature of the arch on surface, but the vein system dips to the south and the hinge zone probably dips to the north. In short, no obvious geometric relationship between the arch and the fracture system is now recognized. In contrast, it is concluded that the Kootenay Florence vein-fault was superimposed on the isoclinally folded and arched formations subsequent to all folding, and that subsidiary fractures are related to the same stresses that produced the fault or to subsequent movements along it. Details of the faulting and fracturing controlled the mineralization.

KRAO

Location.—About 2,000 feet west of Loon Lake.

Status.—Crown-granted claim owned by Krao Mines Limited, of Butte, Mont.

History.—Considerable work was done on the property between 1890 and 1908, after which it was worked intermittently until 1936. Before 1908 the work was done under the direction of A. D. Wheeler, the owner. In 1905 Wheeler is reported to have sold the property for $100,000, and subsequent work was under the direction of W. E. Zwicky or done by lessees. Between 1952 and 1956 Yale Lead & Zinc Mines Ltd. mined underground and shipped most of the material forming the old dump.

Workings.—The principal workings are a shaft inclined at 75 degrees to the west with short levels at 35, 100, and 200 feet below the collar. A stope north of the shaft has broken through to surface. Two short shafts and a number of pits have been made north of the main shaft (*see* Fig. 25).

Geology.—The main workings are along a vein that strikes south 10 degrees west, dips steeply to the west, and follows the western side of the Krao limestone (*see* p. 25). The limestone has grey calcareous quartzite lying west of it, and the contact appears to be a strike fault with minor displacement. Calcite, siderite, and quartz locally with galena and sphalerite occur in the limestone adjacent to the fault. The vein has been stoped for no more than 100 feet north of the shaft, although it has been followed for 240 feet north and 160 feet south of the shaft on the 100 level. Very little mineralization remains in the workings, but old-timers have specimens of wire silver from the mine and report that much of it was in a cross-fracture just north of the shaft and above the 100 level.

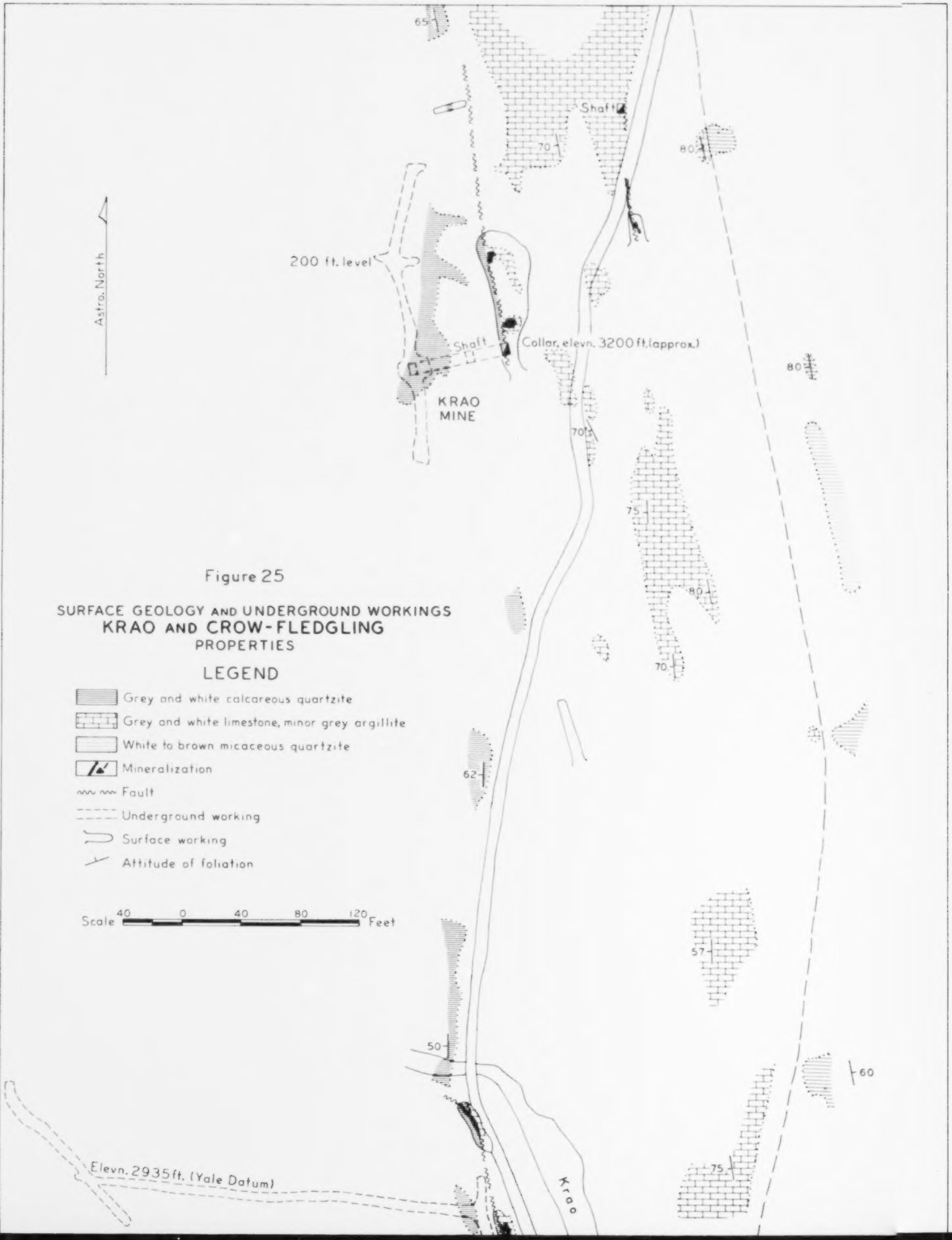
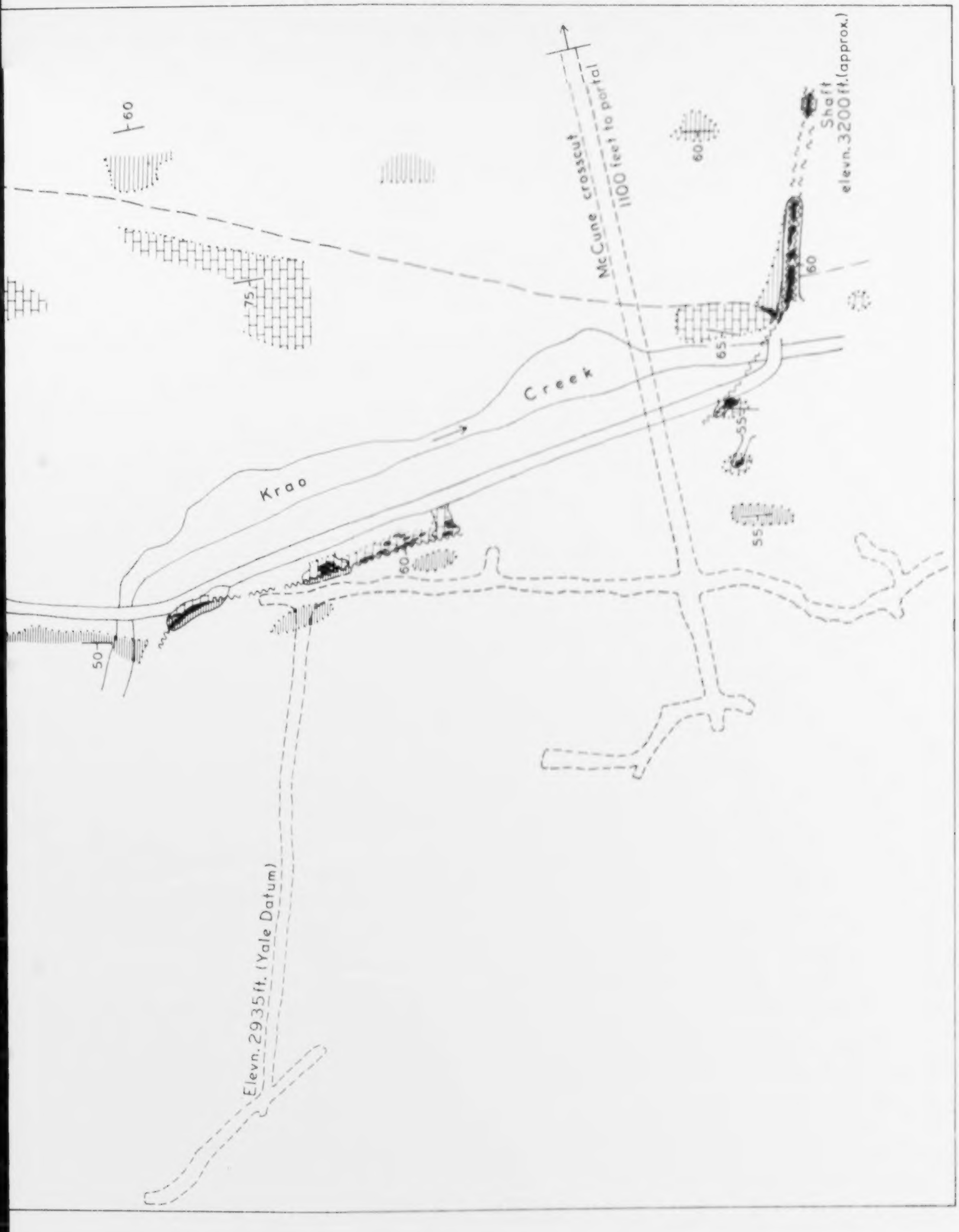


Figure 25

SURFACE GEOLOGY AND UNDERGROUND WORKINGS
KRAO AND CROW-FLEDGLING
PROPERTIES

LEGEND
Grey and white calcareous quartzite
Grey and white limestone, minor grey argillite
White to brown micaceous quartzite
Mineralization
Fault
Underground working
Surface working
Attitude of foliation
Scale 40 0 40 80 120 Feet
Astro. North
Shaft
200 ft. level
Shaft
Collar, elevn. 3200 ft. (approx.)
KRAO MINE
Krao
Elevn. 2935 ft. (Yale Datum)
65
70
80
80
70
75
80
70
62
57
50
60
75


60
75
50
Krao Creek
McCune crosscut
1100 feet to portal
Shaft
elevn. 3200 ft. (approx.)
60
60
65
55
55
60
Elevn. 2935 ft. (Yale Datum)

Ore mined in 1963 by T. Lane, of Ainsworth, was taken from an inclined working 120 feet northeast of the main shaft. It was an irregular pocket of galena along a small northerly trending fault adjacent to an argillaceous lens in the Krao limestone. Some of the galena was in crystals as much as 1½ inches wide.

LADY OF THE LAKE

LOCATION.—Loon Lake.

STATUS.—Crown-granted claim owned by Yale Lead & Zinc Mines Ltd.

WORKINGS.—A few open pits and shallow shafts.

GEOLOGY.—Showings on the Lady of the Lake claim are rusty siderite and quartz containing galena and sphalerite along a poorly defined vein in a limestone on the western shore of Loon Lake. The vein trends northward parallel to the formations.

LIBBY

LOCATION.—North side of Cedar Creek about 4,000 feet west of Kootenay Lake.

STATUS.—Crown-granted claim owned by Western Mines Limited.

GEOLOGY.—*See* page 47.

MILE POINT

LOCATION.—Shore of Kootenay Lake at Mile Point.

STATUS.—Crown-granted claim owned by Yale Lead & Zinc Mines Ltd.

HISTORY.—Mineralization reported to contain as much as 3,000 ounces per ton silver was discovered on the claim in 1892, and two adits were driven in the next few years. The only recorded shipment from the property was made in 1895 and averaged 73 ounces per ton silver. Until recent years one of the adits has been open, but road construction in 1964 covered the portal (*see* Fig. 19).

GEOLOGY.—Mineralization on the Mile Point is near the footwall of the lower Ainsworth limestone. The zone, though irregular in general, lies parallel to the formations. Sorted ore on the dump consists of coarse galena, sphalerite, and pyrite in a gangue of quartz and iron carbonates.

NEOSHO

LOCATION.—Half a mile north of Coffee Creek and about a mile west of Kootenay Lake.

STATUS.—Crown-granted claim owned by Sven Hallgren, of Nelson.

WORKINGS.—Open pits and shallow adit caved in 1963 but reported to trend north 20 degrees west about 200 feet from the portal, and to have gained a depth of only 20 to 30 feet below surface.

HISTORY.—The Neosho was originally worked from 1892 to 1896. Some work was done at intervals until about 1928. The property was acquired by Hallgren in 1948 and worked in 1949 and 1950.

GEOLOGY.—The Neosho workings are in grey knotted schist containing thin layers of fine-grained limestone. The vein is not exposed, but it is reported to have been a zone of sheared and oxidized schist containing galena, sphalerite, and locally wire silver.

NEW JERUSALEM

LOCATION.—South side of Cedar Creek about 1 mile west of Kootenay Lake.

STATUS.—Crown-granted claim owned by D. M. Donnelly, of Los Angeles, Calif.

HISTORY.—The original work on the property was done before 1900. This included surface stripping and underground stoping and an adit crosscut. A raise from the crosscut to the surface workings was driven in 1937 and 1938. Ore was mined from the raise in 1951 and 1952.

WORKINGS.—The workings consist of an adit crosscut at an elevation of about 3,100 feet on the south bank of Cedar Creek driven south 20 degrees west for about 200 feet. The crosscut intersects a vein at about 150 feet from the portal, and drifts to the east and west follow the vein for about 100 feet.

GEOLOGY.—The main vein on the New Jerusalem is in fine-grained hornblende schist with a fairly good foliation dipping 20 to 25 degrees to the west. A lenticular quartz vein which strikes north 60 to 70 degrees west and dips 75 degrees to the south contains galena, sphalerite, minor chalcopyrite, pyrite, and pyrrhotite. The vein is up to 3 feet thick with lenses and clusters of medium- to coarse-grained sulphides 6 to 8 inches thick. Vugs and comb structure are common. The vein is exposed on surface for about 300 feet and has been mined for half this length. Where exposed in the drift about 100 feet below surface, it is only a foot or so thick and poorly mineralized. The stopes do not reach the drift.

NICOLET

LOCATION.—Between Princess and Cedar Creeks about 1,800 feet west of Kootenay Lake.

STATUS.—Crown-granted claim owned by Western Mines Limited.

HISTORY.—The claim was Crown granted in 1897. The principal work recorded was done in 1916 and 1917 and between 1950 and 1952.

WORKINGS.—The workings consist of an old shaft inclined to the west, above which a stope has broken to surface so that the present workings resemble an open pit. Bulldozer strippings have been made east and south of the pit.

GEOLOGY.—The Nicolet is a mineralized fracture in the lower Ainsworth limestone comparable to those in the Lakeshore mine to the north (*see* p. 99). The Nicolet mineralization is along a single mineralized fracture that strikes north 75 degrees west, dips 80 degrees south, and contains coarse galena, sphalerite, pyrite, pyrrhotite, minor chalcopyrite, locally associated with siderite. Pieces of ore on the dump contain also some quartz, calcite, and knebelite. The fracture has been traced for about 300 feet to the east, and throughout its exposed length the sulphides are only a few inches thick, locally expanding somewhat along the foliation or subsidiary fractures. Judging from the shape of the stope, the sulphides there extended several feet from the fracture. Ore is reported to have been mined also from a replacement deposit in the same limestone about 400 feet to the south. Ore in the stope and in this deposit is close to the hangingwall of the lower Ainsworth limestone.

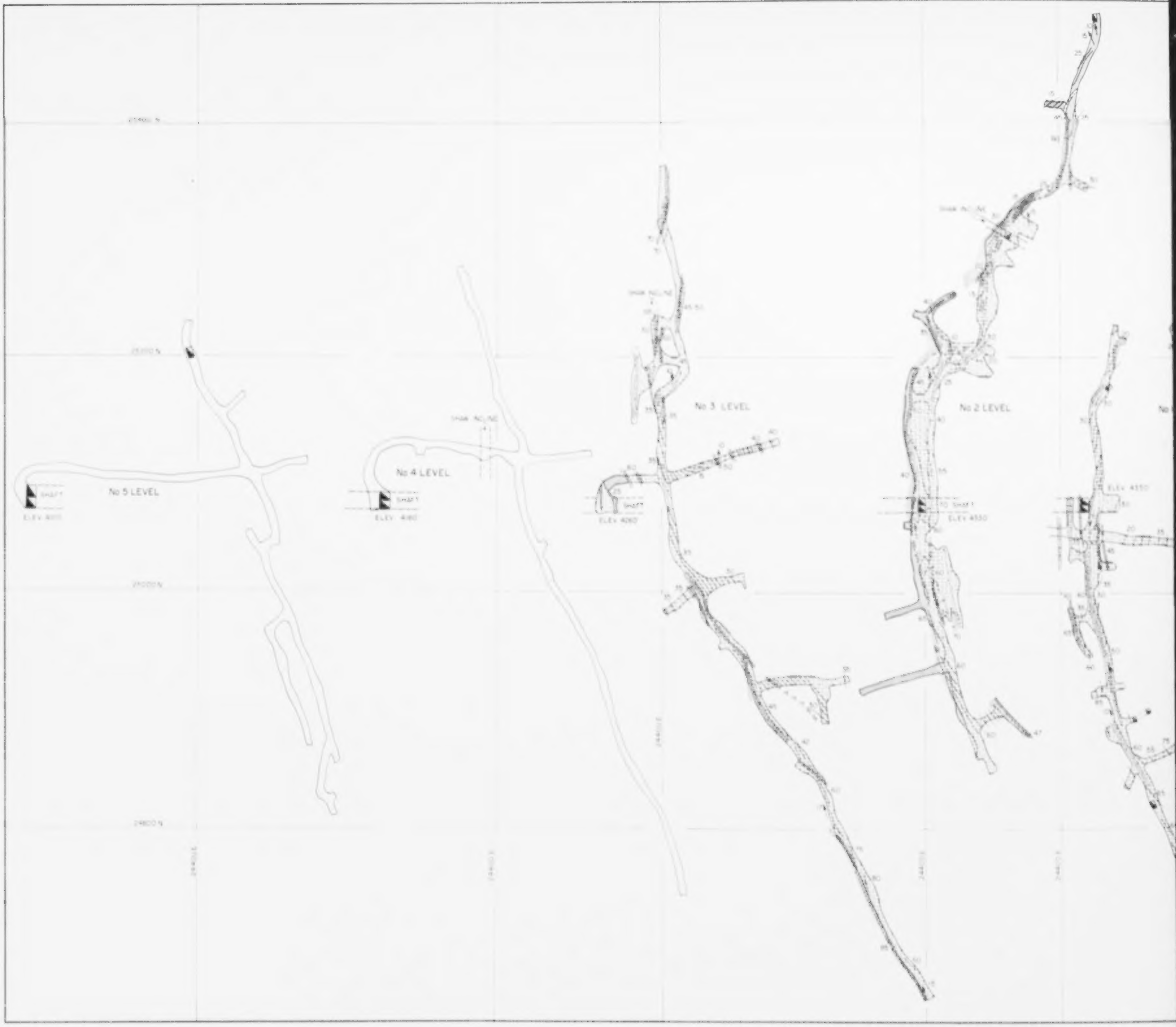
NOAH

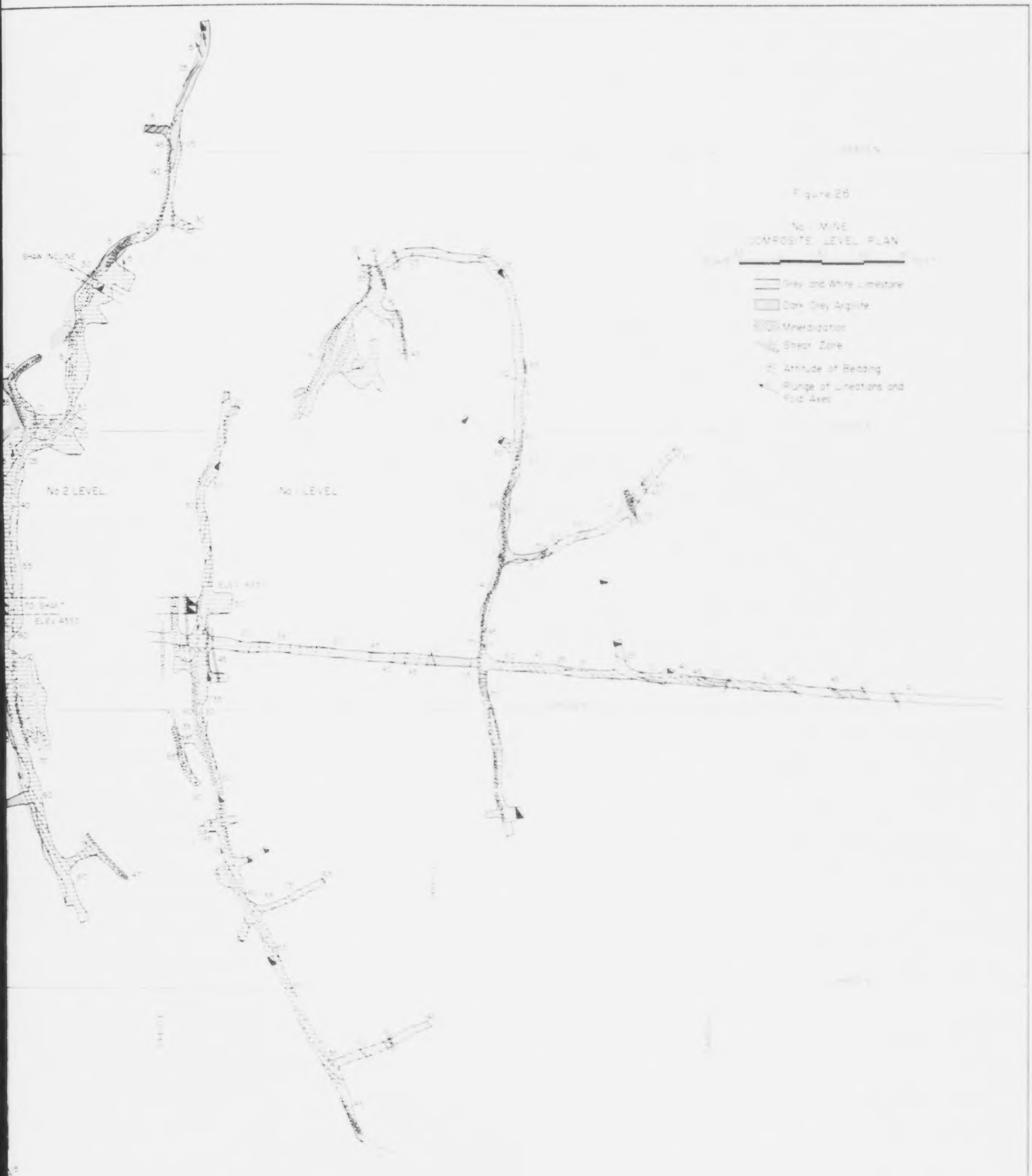
LOCATION.—Shore of Kootenay Lake just south of Woodbury Creek.

STATUS.—Crown-granted claim owned by Western Mines Limited.

HISTORY.—This is an old claim on which the principal work was done by lessees in 1951 and 1952.

WORKINGS.—The adit followed a quartz-carbonate vein up to 10 inches wide containing galena, sphalerite, and pyrite in calcareous rocks of the Early Bird Formation. Mineralization is reported to have reached widths up to 2 feet where calcareous beds were replaced adjacent to the vein. The highway rock cuts above the adit expose a number of veins (*see* p. 117), mainly containing quartz, calcite, and fluorite with little or no sulphides.

25400 N
25200 N
25000 N
24800 N
No 5 LEVEL
SHAFT
ELEV
No 4 LEVEL
SHAFT
ELEV 4160
SHAW INCLINE
No 3 LEVEL
SHAFT
ELEV 4260
SHAW INCLINE
No 2 LEVEL
TO SHAFT
ELEV 4350
SHAW INCLINE
ELEV 4450
No



SHAW INCLINE
No 2 LEVEL
No 1 LEVEL
ELEV 4351
TO SHAFT
ELEV 4330
Grey and White Limestone
Dark Grey Argillite
Mineralization
Shear Zone
Attitude of Bedding
Plunge of Lineations and Fold Axes

Figure 26

No 1 MINE
COMPOSITE LEVEL PLAN

NOBLE 3

Location.—About a mile west-southwest of Ainsworth.

Status.—Crown-granted claim owned by Yale Lead & Zinc Mines Ltd.

Workings.—Several shallow shafts and open pits.

Geology.—The main showings on the Noble 3 claim are along a quartz vein trending north 60 degrees west and dipping steeply to the south. The vein, which is in fine-grained hornblende schist, contains coarse galena, sphalerite, and pyrite locally in well-formed crystals in vugs and cavities between quartz crystals. The vein has been traced for several hundred feet and is less than a foot thick.

No. 5

Location.—North side of Cedar Creek about 1 mile from Kootenay Lake.

Status.—Crown-granted claim owned by G. E. Penrod, of Colfax, Wash.

History.—The claim was Crown granted about 1900, but little work was done until 1954, when an adit was driven to intersect two narrow veins exposed by early surface work.

Geology.—Showings on the claim are in hornblende schists that dip at moderate angles to the west, and near the adit portal contain a lens of white crystalline limestone. The adit, at an elevation of 3,300 feet, follows a shear zone trending north 35 degrees west dipping 65 degrees west and locally containing a foot or so of quartz with galena and sphalerite. Three hundred feet north and somewhat east of the portal the adit encountered a vein striking northwest and dipping 55 degrees to the southwest. The vein is less than a foot wide and contains quartz, galena, and sphalerite.

No. 1

Location.—About 1½ miles west-northwest of Ainsworth, just south of the south fork of Cedar Creek.

Status.—Reverted Crown-granted claim held from time to time by location. In 1965 the ground was open.

History.—The No. 1 is one of the oldest and most productive mines in the camp. Underground work was started in 1888, and a 50-ton concentrator was built on the property in 1893. By 1895 there was more than 3,000 feet of underground workings. The early work was done by a number of different companies and individuals, but production was fairly continuous. In 1910 the property was acquired by Cominco Ltd., which operated the mine until 1921, after which it was operated intermittently by lessees. In 1913 a tram-line was built to the company's mill at the mouth of Cedar Creek. No underground mining has been done for many years, but the workings were accessible in 1960.

Workings.—The workings consist of five levels connected by an internal shaft inclined at 60 degrees to the west. The No. 1 level, the main haulage from the top of the shaft, is at an elevation of 4,300 feet, and the No. 5 level, the lowest, is at 4,100 feet. Open stopes and inclined workings extend to the surface above No. 1 level and between No. 1 and No. 3 levels. A composite diagram of the workings is given on Figure 26.

Geology.—The No. 1 mine is in limestones and dark-grey argillites in a low grade of regional metamorphism near the eastern edge of the fourth fault slice (*see* p. 32). The limestone, called the No. 1 limestone, is a few hundred feet thick in the mine area and consists of fine-grained blocky grey and white rock with local lenses of black argillite. Black argillite or very fine-grained dark-grey phyllite lie to the east and west.

These rocks are involved in a series of relatively open folds which in general plunge to the north, have axial planes dipping gently west, and in over-all form are S-shaped in section looking north. Part of one of these folds is exposed in the mine and was illustrated by Schofield (1920, p. 52). A more complete section and the general pattern of folding from the No. 1 to the Silver Hoard mine half a mile to the north is shown on Figure 27. In addition to these open folds, which are called Phase II folds (*see* p. 34), minor isoclinal folds are seen locally which are older than the Phase II folds and are significant in the mine area in causing the rock units to be lenticular.

Although there are many shear zones in the mine, only one significant cross-fault is present. It strikes northwest and dips 45 degrees to the northeast and is exposed near the portal of the No. 1 level as well as on the level to the north and in workings above. Traced northward it swings to the north and flattens in dip.

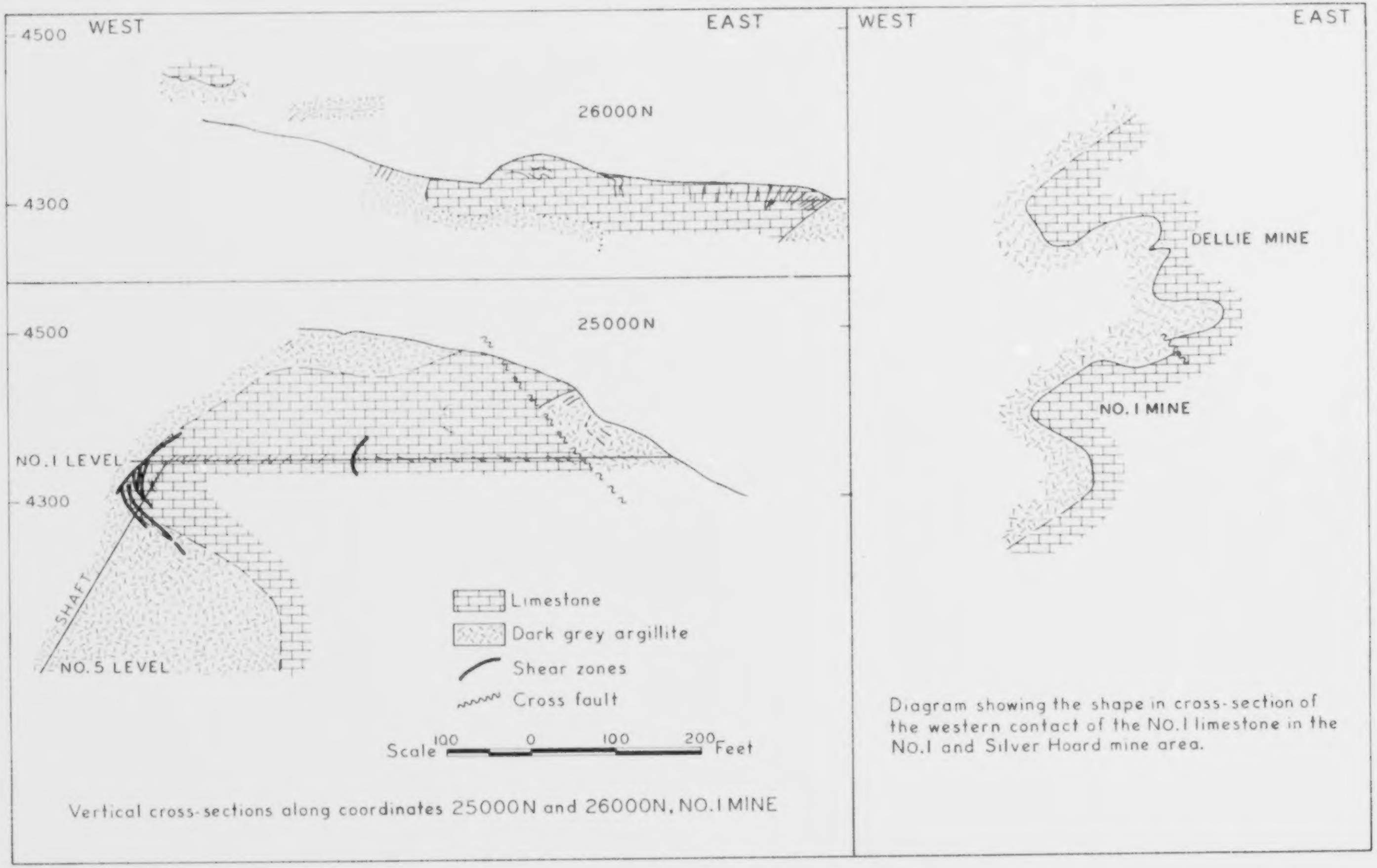
Orebodies in the mine are in the No. 1 limestone along sheared and crushed zones at or near the western contact of the limestone. These zones are related to the Phase II folds, and are widest and most intense at the fold hinges. They consist of zones of fractured and brecciated limestone cemented by calcite and locally by siderite. Only a few specks of galena, sphalerite, and pyrite are to be found in the walls of the old stopes and on the dumps, and the nature of the ore is uncertain. Old-timers report that even during the years of production it was difficult to estimate the grade on inspection, though the average grade of the ore shipped was about 50 ounces per ton in silver. Schofield (1920, p. 51) describes ore from the upper part of the mine as follows:—

"The ore consists of a dark brown, decomposed mass consisting mainly of iron oxide, some lead carbonates, and wire silver. In places sulphide ore is visible and shows the presence of galena and zincblende with some pyrite and chalcopyrite. The gangue is chiefly silicified and altered limestone which sometimes shows traces of sulphides of lead and zinc. The limestone when occurring in the ore shows the development of quartz crystals in cavities. The metallic sulphides often penetrate into the limestone of the footwall as minute stringers and replacement masses, but in no case were any cross-veins seen which might represent avenues through which the ore solutions passed."

Rusty walls are found in many of the stopes, and it is probable that all the ore was somewhat oxidized and the silver may have been enriched.

Because the orebodies are along shears associated with folding, they plunge to the north at low angles. On the No. 1 level a well-mineralized hinge zone is present at the collar of the shaft (*see* Fig. 27).

In the crosscut 200 feet east of the shaft the same hinge zone strongly sheared along a sliver of black argillite in the limestone was followed by a drift both to the north and to the south but is not significantly mineralized. Stopes along the hinge zone south of the shaft dip deeply and are 10 to 20 feet wide. Stope walls show two or three crushed zones each a few inches to 4 feet wide that were locally mined together. Toward the south they become thinner and less well defined. The stopes flatten to a low westerly dip upward and steepen through vertical to a moderate easterly dip below No. 1 level. They extend to surface on the upper westerly dipping limb and continue a relatively short distance down the easterly dipping limb. Exploration below No. 3 level in rocks that dip to the east exposed a number of shear zones, some in the limestone near the argillite contact and some to the west in the argillite itself. Mineralization in the shear zones is narrow and discontinuous.


4500
WEST
EAST
26000N
4300
4500
25000N
NO. I LEVEL
4300
SHAFT
NO. 5 LEVEL
Limestone
Dark grey argillite
Shear zones
Cross fault
Scale 100 0 100 200 Feet
WEST
EAST
DELLIE MINE
NO. I MINE

Vertical cross-sections along coordinates 25000N and 26000N, NO. I MINE

Diagram showing the shape in cross-section of the western contact of the NO. I limestone in the NO. I and Silver Hoard mine area.

Figure 27. Vertical cross-sections, No. 1 mine area.

SILVER HOARD

LOCATION.—Between Cedar Creek and the south fork of Cedar Creek 1½ miles west of Kootenay Lake.

STATUS.—Silver Hoard Mines Limited, of Toronto, owns a number of Crown-granted claims, including the Dellie, Dellie Fraction, Little May, No. 1 Fraction, No. 2 and No. 3 Fractions, and Silver Hoard, centred around the Dellie mine.

The property is referred to as the Silver Hoard because of the continued association with the Silver Hoard company. The principal mine is the Dellie, but there are also workings now inaccessible on the Little May, Silver Hoard, and other claims in the group.

HISTORY.—Development and mining at the No. 1 mine was closely followed by prospecting and exploration along the No. 1 limestone both to the north and to the south. The Dellie was discovered before 1900, and the main shaft was sunk 100 feet in 1912. The most continuous period of production was between 1912 and 1927. Original development was done by the Silver Hoard Mines Limited, of Spokane, which built a 60-ton mill about 1920. Very little mining has been done since 1927. In 1948, 1949, and 1950 the mine was operated under lease by W. Lane, of Ainsworth.

WORKINGS.—The mine is a series of complicated level workings connected by a 45-degree shaft inclined to the northwest, and by a series of open stopes and raises. Parts of the workings are shown on Figure 28.

GEOLOGY.—The orebodies in the Dellie mine are at or near the contact of the No. 1 limestone with black argillites that lie to the west, and are associated with shear zones along this contact. The geology of the Silver Hoard area closely parallels that at the No. 1 mine (*see* p. 103). Several tight to open folds, with axial planes dipping gently to the west, found between the No. 1 mine and the Silver Hoard property are sketched in a cross-section on Figure 27. In the Dellie mine these folds plunge 20 to 30 degrees to the south, forming part of a local reversal in the regional low plunge to the north.

The orebodies in the mine are at or near the contact of the No. 1 limestone with black argillites that lie to the west and are associated with shear zones along this contact. The shear zones are near the hinge of a sharp-crested fold exposed in limestone in the main shaft. The axial plane dips gently to the west and the axis plunges to the south. The hinge zone in most of the mine area is close to the 100 level; west- and southwest-dipping shears on the upper limb lie above the level, and east-dipping shears lie below. The two sets of shears which in general strike north to northwest intersect, die out, and overlap in a complicated zone near the hinge of the fold along which most of the stopes have been made. At one place northwesterly trending shears dipping to the northeast transect the other structures, causing a left-hand offset of the west-dipping layers in the upper part of the mine.

Much of the original ore was oxidized and rich in silver. Pillars in some stopes on No. 100 level contain lenses of white calcite, siderite, and minor quartz along with coarse galena, sphalerite, and pyrite. Schofield describes wire silver occurring in cracks in the limestone and also refers to green fluorite as part of the gangue.

The southward plunge of the fold in the Dellie mine brings the favourable contact to surface to the north near workings on the Little May. Several old workings have been made to the south, where the contact, because of the folding and poor outcrop, is to be found at many unexpected places.

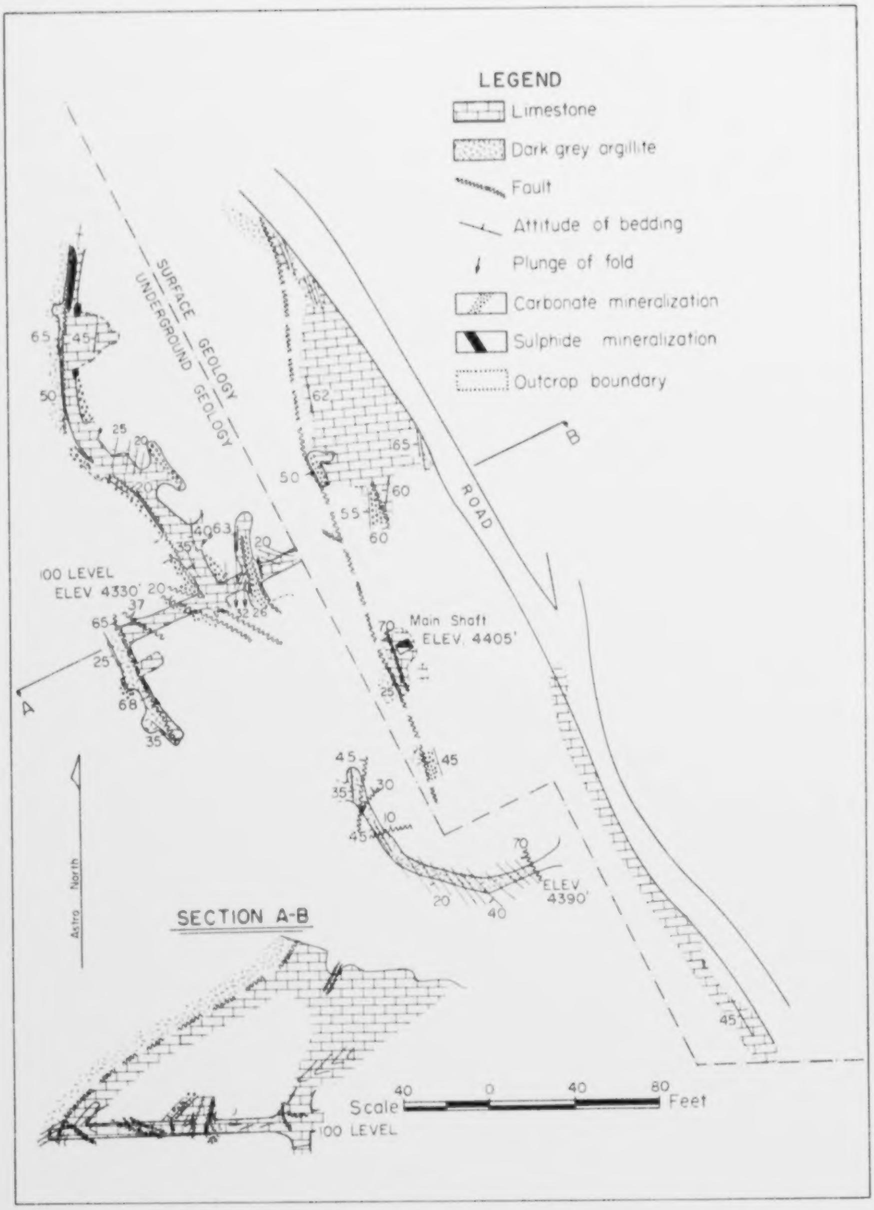

LEGEND
Limestone
Dark grey argillite
Fault
Attitude of bedding
Plunge of fold
Carbonate mineralization
Sulphide mineralization
Outcrop boundary
SURFACE GEOLOGY
UNDERGROUND GEOLOGY
ROAD
B
A
100 LEVEL
ELEV. 4330'
Main Shaft
ELEV. 4405'
ELEV.
4390'
Astro North
SECTION A-B
Scale
40
0
40
80
Feet
100 LEVEL
65
45
50
25
20
20
40
63
35
20
20
37
32
26
65
25
68
35
62
165
50
60
55
60
70
25
45
45
35
30
10
45
70
20
40
45

Figure 28. Geology of the Dellie mine.

SILVER GLANCE

Location and Status.—A group of five formerly Crown-granted claims south of Lendrum Creek 1¼ miles from Kootenay Lake is described here under the heading of Silver Glance, the principal remaining Crown-granted claim of the group. The other claims include the Hercules (formerly Pataha), Sullivan (formerly Ellen), Noranda (formerly Bugaboo), and Attended. They form part of a group held for some time by Triumph Mines Limited and currently owned by Blue Star Mines Limited.

Workings.—An adit on the Silver Glance claim (*see* Fig. 3) is 1,050 feet long and has been collared on the south bank of Lendrum Creek. A second adit 380 feet in elevation above the Silver Glance is on the Noranda claim at the top of the slope south of the creek. In addition to the Silver Glance and Noranda adits, two short adits on the Sullivan claim and several open cuts have been made at intervals for about 1,200 feet south of the Noranda adit. Several open pits have been made on the Hercules claim about half a mile south of the Noranda adit.

History.—The Silver Glance claim was located in 1896, and the adit driven more than 200 feet before 1900. There is no record of work on this or the other claims between 1900 and 1951, when three of the cancelled Crown-granted claims were staked by T. Hawes, of Ainsworth. Between 1951 and 1957 considerable trenching, diamond drilling, and some underground work were done, mainly by Triumph Mines Limited. The adits on the Noranda and Sullivan claims were driven during this time. In 1964 and 1965 ore was mined from the Noranda adit and shipped to the Yale mill at Ainsworth. Much of the exploration on these claims was under the direction of C. Lind, of Kaslo.

Geology.—The principal rocks on the Silver Glance group are dark-grey knotted schists and fine-grained blue-grey limestone, the Star limestone, which strike to the north and dip at low to moderate angles to the west. They are transected by several northwesterly trending faults which dip to the south. Mineralization is along these faults in a narrow band of limestone which gradually becomes thinner in going northward from the Hercules claim. On this claim it is about 150 feet thick and pinches out about 600 feet north of the Noranda adit. A much thicker limestone occurs to the west of the workings but is not known to be mineralized, and several outcrops of limestone are found to the north above the road to the Silver Glance adit which, because the outcrops in that area are scarce, cannot be clearly related to the mineralized limestone.

Isolated masses of fine-grained granite outcrop on the Noranda claim, and a thick granitic sill is exposed in the Silver Glance adit and on the road to the adit portal.

Mineralization consists of quartz and siderite containing galena, sphalerite, pyrite, pyrrhotite, and minor chalcopyrite. It occurs along the faults as vuggy and crustified veins and along fractures in the limestone. Locally, as in the Noranda adit, a mineralized zone follows the western contact of the limestone where it has been fractured and warped close to a fault.

The Silver Glance adit follows a fault, called the Silver Glance fault (*see* p. 44), that strikes north 50 degrees west and dips 60 to 70 degrees to the south. Some mineralization rich in silver is reported to have occurred near the adit portal, and minor amounts of sulphides are found where the fault transects a narrow layer of limestone about 650 feet from the portal. This limestone is thought to be the layer that is well mineralized in the Noranda adit, and considerable surface drilling has been done to test the ground between these two workings where the fault intersects the limestone. In the Noranda adit, lead-zinc mineralization up to 4 feet thick was followed for almost 100 feet. This mineralization was essentially mined out in 1964 and 1965 and amounted to 2,400 tons. It was found to be along the western side of the limestone, where it was warped into a northeasterly strike south of the Silver Glance fault, and along some complex fractures near this warp. The ore pinched out down dip below the adit, and the surface drilling between this and the Silver Glance adit found only scattered mineralization.

SILVER COIN

LOCATION.—North side of Woodbury Creek about 4 miles by road from Kootenay Lake. The workings are about 500 feet northeast of the first bridge over Woodbury Creek.

STATUS.—Located claim held by Alex Grant, of Ainsworth.

WORKINGS.—Four short adits between elevations of 3,400 and 3,650 feet, all of which were caved at the portal in 1963.

HISTORY.—Ore was shipped by a number of different lessees between 1938 and 1946.

GEOLOGY.—The workings on the Silver Coin are in steeply dipping shear zones in carbonaceous and limy argillite and dark-grey limestone. They lie within 100 feet of a layer of massive purplish argillite to the west and are close to an irregular mass of light-grey dolomite to the east. The purplish argillite and the calcareous rocks containing the showings strike north and dip steeply west. The shear zone has about the same attitude but probably dips more steeply than the formations. It contains stringers and lenses of quartz and calcite reported to carry small amounts of galena, sphalerite, tetrahedrite, and argentite (*see* Rice, 1941, p. 80).

SKYLINE

LOCATION.—South side of Krao Creek 2½ miles west of Kootenay Lake.

STATUS.—Crown-granted claim owned by Alfred W. McCune and associates, of Santa Barbara, Calif.

WORKINGS.—The workings consist of a series of open trenches at an elevation of 5,600 feet along a line running south from 300 to 600 feet south of Krao Creek. A large dump west of these trenches is beside a caved shaft, and the caved portal of a long crosscut is about 1,000 feet to the east of the trenches at an elevation of 5,200 feet.

HISTORY.—The Skyline was Crown granted in 1890 by A. D. Wheeler and actively developed between 1889 and 1900. Most of the trenches and the shaft were made at this time. Between 1916 and 1918 the crosscut at an elevation of 5,200 feet was driven, and in 1920 and 1921 a raise was driven near the western end of the crosscut. There is no published record of work since that time, and in the currently accessible workings very little mineralization is exposed. Shipments of ore from the Skyline have the highest grade in silver of any recorded in the Ainsworth camp.

GEOLOGY.—The workings on the Skyline are in the No. 1 limestone and in dark-grey to black phyllites and argillites associated with it. The showings are in the limestone within a few hundred feet of the eastern margin of the Nelson batholith. McConnell (1895) gives the following description of the deposit: "The workings on the Skyline include an incline 87 feet deep sunk on the lead, and a shaft farther to the west, 200 feet deep, from the bottom of which a drift 120 feet in length and an upraise of 40 feet lead to the incline and the chamber of ore now being worked. The Skyline ore consists of porous siliceous rock carrying a dark mineral probably mostly argentite, native silver, and galena along with some grey copper (tetrahedrite) and iron and copper pyrites. It averages 45 to 50 ozs. in silver per ton." In the Annual Report for 1921 (p. 120) the ore is described as disseminated galena and copper in a quartz gangue and is characterized by bright-blue and green stains on the fractured surfaces.

Near the upper workings the limestone strikes north 10 degrees east and dips steeply to the west. In one of the old trenches a stockwork of rusty carbonate quartz and calcite as much as 10 feet thick lies more or less parallel to the foliation in the limestone. Scattered grains of galena are present in material from the stockwork on the dump.

STAR, SUNLIGHT

LOCATION.—One and a quarter miles northwest of Ainsworth.

STATUS.—Crown-granted claims owned by D. H. Norcross, of Nelson.

GEOLOGY.—The following report by G. E. P. Eastwood is taken from the Annual Report for 1952, pages 166 to 168:—

Most of the workings are on and near the northwest part of the Sunlight claim. One old shaft, now completely caved, was sunk in 1899 and yielded a few tons of ore. Three inclined shafts are on the east brow of a low ridge running through the middle of the area of the accompanying map (*see* Fig. 29). The north shaft descends about 30 feet to a sublevel which follows a northwesterly cross-fault for about 80 feet then connects by a short raise with the face of an adit, 65 feet lower than the shaft collar. This adit was started north of the cross-fault, intersected it at 200 feet from the beginning of bedrock, and followed the fault for a further 50 feet. The sublevel could not safely be entered in 1952 without ropes and it is omitted from the map. A second adit, not shown, was driven from 1904 to 1911 for about 800 feet from a point about 400 feet east-southeast of the first and 190 feet lower. It is inaccessible, but is reported to have struck no ore. Two old shafts south of the area of Figure 29 were not examined. Between 1947 and 1956 considerable mining and diamond drilling were done on the property by the owner and by Privateer Base Metals Limited.

The country rock consists of interbedded limestones and metamorphosed argillaceous rocks, complexly folded, intruded by a sheet of fine-grained quartz diorite, and displaced by an ore-bearing cross-fault. Details of the stratigraphy are obscured or rendered uncertain by the complexity of the folding. In general, there appears to be at least 150 feet of limestone, sandwiched between argillaceous rocks which have been metamorphosed to variable degrees. Beds and lenses of schist, phyllite, and argillite in the limestone are common in drill cores but are not noticeable on surface or in the mine openings. The limestone is mostly medium grained and medium grey in colour, but for a thickness of about 50 feet near the middle it is very fine grained, thin bedded, and cherty looking. This fine-grained limestone has largely been contorted, brecciated, and cemented with coarse-grained white calcite. Near the cross-fault it is minutely and intricately dragfolded, with some suggestion of pulverization.

The quartz diorite body intrudes medium-grained limestone at surface and in the upper adit. The dip of the west contact is 45 degrees west where exposed, but drill-hole evidence indicates steepening of the hangingwall past the vertical at about 50 feet below the adit level. The cross-fault cuts the quartz diorite along one of two jogs producing a left-hand offset of the hangingwall contact of about 25 feet.

The pattern of folding is incompletely known, but appears to be exceedingly complex in detail. Nearly every drill core shows wide variations in the angle between core and bedding, and small dragfolds are common. On surface south of the fault the pattern of attitudes and of exposures of the fine-grained limestone suggest a small

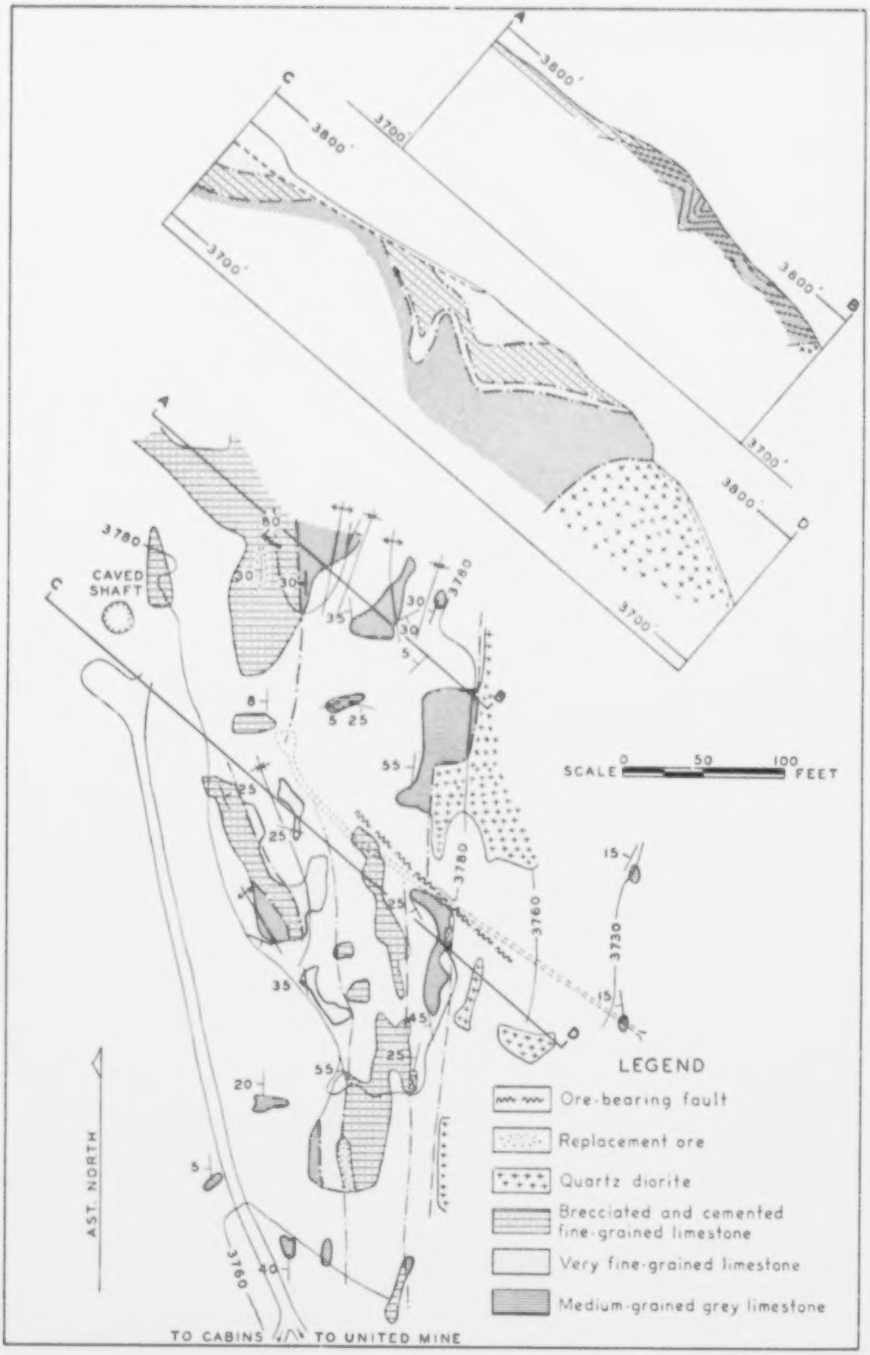

A
C
3800'
3700'
3800'
3700'
3600'
B
3700'
3800'
D
3700'
A
3780
CAVED SHAFT
C
80
30
30
35
30
30
3780
5
8
5 25
B
55
SCALE 0 50 100 FEET
25
25
3780
25
3760
15
3730
35
15
45
25
D
55
20
5
40
3760
AST. NORTH
LEGEND
Ore-bearing fault
Replacement ore
Quartz diorite
Brecciated and cemented fine-grained limestone
Very fine-grained limestone
Medium-grained grey limestone
TO CABINS
TO UNITED MINE

Figure 29. Geological plan and section of the Star mine.

syncline and anticline dying out southward. North of the fault, attitudes in the medium-grained limestone suggest two anticlines and synclines; one anticlinal crest is vaguely discernible. Underground there is a reversal of dip south of the fault, suggestive of a syncline. No other folds were seen underground, but some must be assumed to explain the occurrence of fine-grained limestone south of the fault at the head of the raise from the adit face. The pattern of section C-D is an interpretation of the available data. Underground north of the fault the beds dip steeply into the quartz diorite hangingwall.

The fault is exposed only in the north shaft, sublevel, and inner part of the upper adit. It strikes north 50 degrees west and dips 75 to 87 degrees southwest, steepening downward. It is filled with a sheeted vein of coarsely crystalline white calcite, 2 to 4 feet thick. Both walls of the calcite vein contain veins of sphalerite and galena which thicken and thin in complementary fashion, so that the aggregate thickness of ore minerals is roughly constant at 10 to 12 inches. Some of the drilling was designed to pick up the continuation of the fault to the northwest, but evidence of the fault was less and less conclusive at increasing distances from the north shaft. One hole intersected two 2-foot veins of coarsely crystalline white calcite and a narrow zone of friable oxidized material, all widely separated from each other; and another hole, farther to the northwest, cut three 1-foot calcite veins and several narrow oxidized zones. It seems probable that the fault feathers out to the northwest, but there is no surface evidence bearing on this. The direction and amount of movement on the fault are unknown.

Sphalerite and galena are in places disseminated in the limestone, and in at least three places have made replacement ore. One small replacement orebody is in medium-grained limestone in the fault footwall, at the west end of the sublevel. The only suggestions of ore control are a steepening of bedding and proximity of the overlying very fine-grained limestone. Two replacement orebodies are in brecciated fine-grained limestone on surface, respectively north and south of the fault. The south one has been opened by a small open cut at the hangingwall of brecciation. Veinlets of ore minerals extend from it up into the unbrecciated very fine-grained limestone. The north orebody appears to follow a lens of definite and uniform bedding within the brecciated unit. A few feet farther north a minor shear contains a little calamine. The two south shafts along the brow of the ridge appear to have followed lean replacement mineralization.

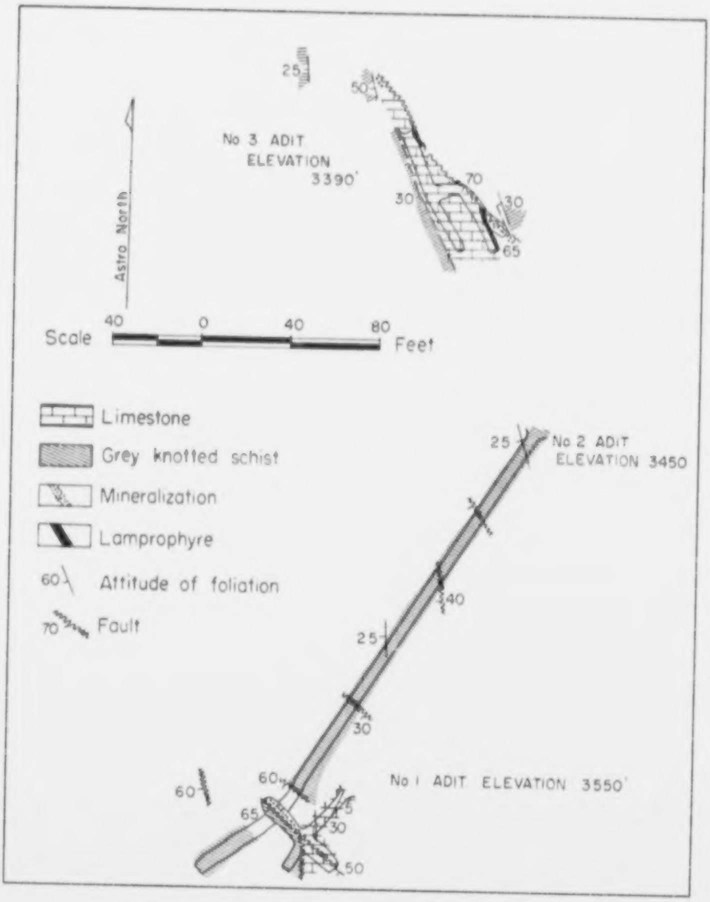
Most of the diamond drilling was directed toward finding additional replacement orebodies in either wall of the fault. Two holes cut a 12-inch band of replacement ore at a point north of the fault and east of the first-mentioned replacement body. A third hole cut 16 inches of replacement ore which may be a continuation of the north orebody in the brecciated limestone. Small amounts and traces of sphalerite, galena, and chalcopyrite were intersected at least once in 10 of the 18 holes. In general, there seemed to be a decrease in occurrence of ore minerals toward the northwest.

TIGER

LOCATION.—South side of Cedar Creek 1 mile west of Kootenay Lake.

STATUS.—Crown-granted claim owned by Helen Wragge, of Nelson.

HISTORY.—The Tiger claim was Crown granted in 1893, and considerable work, including several hundred feet of underground exploration, was done before 1912. A small shipment of ore was made from the claim by T. B. Hansen in 1928, and there is no record of other work on the claim. Undergrowth on the claim is thick, outcrops are scattered, and the old workings are quite obscure.



25
50
No 3 ADIT
ELEVATION
3390'
70
30
30
65
Astro North
Scale
40
0
40
80
Feet
Limestone
Grey knotted schist
Mineralization
Lamprophyre
60 Attitude of foliation
70 Fault
25
No 2 ADIT
ELEVATION 3450
40
25
30
60
60
No 1 ADIT ELEVATION 3550'
65
5
30
50

Figure 30. Map of the main workings, Tiger claim.

Workings.—In addition to the adits shown on Figure 30, there are several trenches north and south of No. 1 adit and south of No. 3 adit.

Geology.—Rocks on the claim are grey knotted schist with narrow interlayers of fine-grained grey limestone. A relatively thick layer of limestone continues northward from the Star property, and thin discontinuous layers found east of it contain the mineralization on the Tiger claim. The rocks dip to the west at moderate angles, and in No. 1 adit and near the face of No. 2 adit contain folds that cause local low dips to the east and south.

The mineralization is associated with two small faults striking northwest and dipping 60 to 70 degrees to the southwest. Veins along the faults contain galena, sphalerite, pyrite, and minor chalcopyrite associated with quartz and siderite. Rusty-weathering siderite extends irregularly out from the veins into the limestone and locally carries sulphides. The veins and rusty siderite together form mineralized zones up to 4 feet thick. The one in No. 1 adit is about 20 feet long and the one near No. 3 adit is at least 100 feet long. Lenses with appreciable sulphides are generally less than 2 feet thick and follow the veins.

TWIN

LOCATION.—About 4,000 feet west of the Florence townsite.

STATUS.—Crown-granted claim owned by Western Mines Limited.

WORKINGS.—The claim covers a number of showings on which open cuts and shallow underground workings have been made. These include the No. 1 level of the Kootenay Florence mine in the eastern part of the claim, the Scott Price and Treggar tunnels on the southern part of the claim, and a number of shallow workings on a series of veins, called North Twin veins, in the northern part of the claim.

HISTORY.—Considerable prospecting and some underground work was done before 1900, but little of this work is described in old reports. Between 1949 and 1956 lessees shipped ore mainly from dumps near the No. 1 level of the Kootenay Florence mine and from the Scott Price tunnel.

GEOLOGY.—The main formations on the claims are fine-grained grey mica schists and micaceous quartzites and two layers of green hornblende schists. The mica schists and the eastern layer of hornblende schist contain thin lenses of impure limestone. Pods of sulphides along the Florence vein system where it passes through these formations have been the aim of exploration and mining on the Twin claim. In the No. 1 level of the Kootenay Florence mine a vein follows a fault that strikes north 70 degrees west and dips 45 degrees to the south. The fault passes from grey mica schist into hornblende schist on the west, and in hornblende schist a lens containing galena, sphalerite, pyrite, chalcopyrite, and quartz up to 4 feet thick and 150 feet long is exposed on the level. To the east, a series of fractures along the same fault are mineralized where they cross a narrow lens of impure limestone in mica schist. Sphalerite and galena have spread out from the fractures along the limestone for about 10 feet. Old trenches and bulldozer strippings west up the hill from the No. 1 level failed to find mineralization along the projection of the fault, but a series of fractures on strike up the hill that are mineralized constitute the North Twin veins. They are in hornblende schist just west of the Josephine fault (*see* p. 19). Half a dozen fractures in a zone about 100 feet from north to south are exposed in a cliff of hornblende schist about 75 feet high. In general the fractures strike somewhat north of west and are vertical or dip steeply north. They contain lenses of sulphides and quartz up to about 2 feet thick. Above the cliff a few hundred feet to the northwest a trench and shallow adit expose a vein containing siderite, vuggy quartz, sphalerite, galena, and pyrite in grey knotted schist, just west of the Josephine fault.

The Scott Price tunnel follows a vein striking between west and north 80 degrees west dipping 60 to 75 degrees south and containing galena, sphalerite, pyrite, siderite, and quartz. The vein is up to 4 feet wide where exposed on surface and is entirely within fine-grained hornblende schist.

UNION

LOCATION.—About 1 mile west of Loon Lake.

STATUS.—Lapsed Crown-granted claim relocated by H. S. Currie, of Ainsworth.

WORKINGS.—Several open cuts and shaft inclined at about 40 degrees to the west.

HISTORY.—The Union was Crown granted in 1896, and most work was done between 1890 and 1900. The shaft is reported to have been sunk 85 feet in 1890. In 1963 and 1964 the old showings were opened up by bulldozer and a " cat " road was built from the United property.

GEOLOGY.—The showings are in grey and white fine-grained limestone, part of the Star limestone. They consist of scattered occurrences of rusty gossan in pockets in the limestone. In the shaft a layer of gossan up to 1½ feet thick lies parallel to the banding in the limestone, which strikes north and dips 40 degrees west. A few blocks of limestone on the dump contain clusters of galena and sphalerite. One hundred and fifty to two hundred feet south of the shaft a fault striking north 20 degrees west and dipping 60 degrees south is exposed in a trench. Galena and minor sphalerite are piled beside the trench, and some galena is exposed in it. Sixty feet north of the shaft a rusty zone containing minor galena is exposed in a bulldozer trench at the contact of limestone and dark-grey schist east of and beneath the limestone.

UNITED

LOCATION.—About 4,000 feet west of the north end of Loon Lake.

STATUS.—Crown-granted claim owned by Yale Lead & Zinc Mines Ltd.

WORKINGS.—The workings consist of a two-compartment shaft inclined at 60 degrees to the southwest, reported to be 235 feet deep, and three level workings from the shaft. The shaft was not accessible during the years of the present study.

HISTORY.—Most of the work on the United was done before 1910. Shipments of ore were made between 1918 and 1920. The property was drilled by the present owners in 1950, and much of the old dump near the shaft was trucked to the Yale mill in 1952.

GEOLOGY.—Mineralization exposed in a trench northwest of the shaft and at the collar of the shaft is along a vein in fine-grained hornblende schist which strikes northwest and dips 60 degrees to the southwest. The vein contains quartz, galena, sphalerite, pyrite, and minor chalcopyrite, and is about 2 feet thick. The trench is within 50 feet of the Josephine fault (*see* p. 19), which separates the hornblende schist from grey knotted schist and intercalated minor limestones to the west. The vein is not found west of the Josephine fault, and probably it swings northward into the fault.

WOODBURY CREEK

A group of claims, in the lower canyon and near the mouth of Woodbury Creek, cover some of the earliest discoveries in the camp. The claims include the Amazon, August Fraction, Budwiser, Dixie, Lulu, Noah, and Vigilant Crown grants, of which the Amazon, Dixie, and Lulu have reverted and have been relocated under the same or different names, and the Nameless Fraction, a located claim on the shore of Kootenay Lake. A few tons of sorted ore was shipped from these veins in the early days, and a custom mill was built on the north side near the mouth of the creek in 1896 (*see* Ann. Repts., 1896, p. 93; 1899, p. 699). In 1948 L. D. Besecker, who had recently come to live at the ranch on the delta of the creek, cleaned up the old mill, shipped 10 tons of concentrate, and began prospecting the old claims. From then until 1956 many of the veins were actively developed, and a total of 5,859 tons of ore was shipped. The work was done mainly by small companies and lessees, but Dr. Besecker maintained an interest in the properties, and under his direction a small custom mill was built in 1952 and 1953 on the north side of the delta. The mill, with a capacity of 75 tons per day, was operated intermittently by the Can-American Mining and Milling Company Ltd. until 1957, and in 1964 was sold and dismantled.

The principal workings on the claims, shown diagramatically on Figure 31, are shallow adits and surface workings made intermittently over a period of years mainly since 1948. The Vigilant adits, the most northerly in the area, are on the eastern slope of Woodbury Creek, one just above the creek and the other about 100 feet in elevation above the first. They trend eastward along a vein that has been

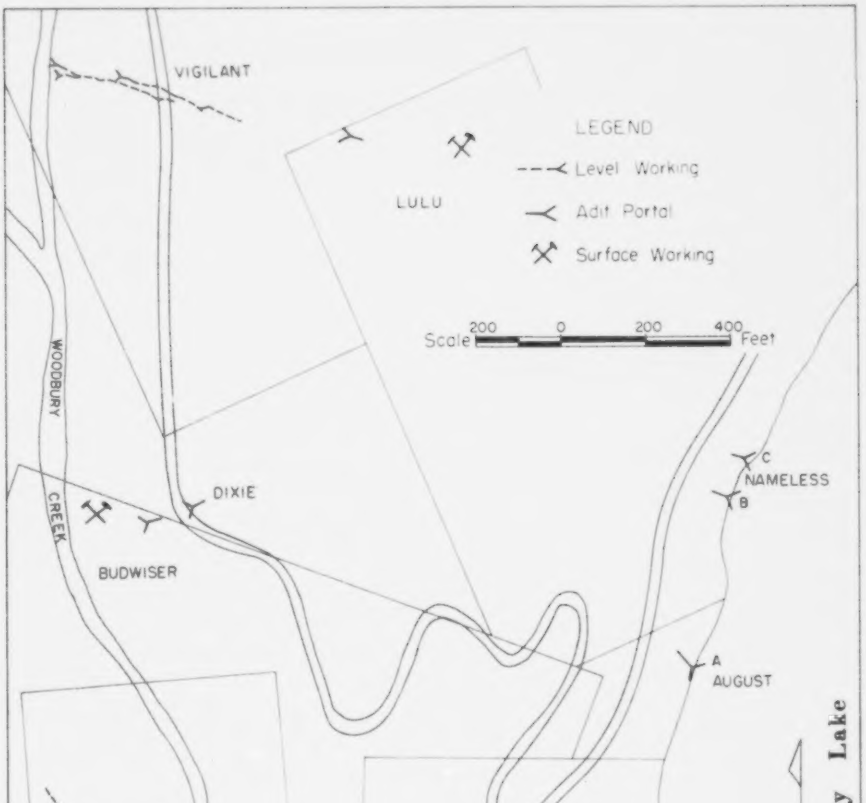

VIGILANT
LEGEND
Level Working
Adit Portal
Surface Working
LULU
Scale 200 0 200 400 Feet
WOODBURY CREEK
DIXIE
BUDWISER
C
NAMELESS
B
A
AUGUST
Kootenay Lake
AMAZON
②
①
Astro North
WOODBURY ADIT

Figure 31. Sketch showing the main workings in the lower Woodbury Creek area.

stoped between them and above the upper one. A short adit and a bulldozer stripping to the east at the portal of an old working on the Lulu claim appear to be on the same vein. Workings on the Budwiser and Dixie claims include narrow trenches and two short adits. On the Amazon the workings are in the canyon of Woodbury Creek just above creek level. In 1965 all workings on the south and west side of the canyon were connected by the Woodbury adit, which is a few tens of feet below adit Nos. 2 and 3. Adits on the August and Nameless claims are about at high-water level on Kootenay Lake. The one on A vein is about 100 feet long and on the B and C almost 300 feet long. Some stoping has been done along them, particularly on the B vein, which has been stoped to about 50 feet below the level as well as above the level.

The claims on lower Woodbury Creek cover many veins and fractures that strike east and dip steeply to the south. They are well exposed along the highway and lake-shore north and south of the creek and up the canyon for half a mile from the highway. By prospecting, several veins have been traced onto the ridge between the canyon and the lake.

The mineralized veins and fractures are in the Early Bird Formation (*see* p. 21) of fine- to medium-grained calcareous and siliceous mica schist. Calcareous layers and lenses containing biotite and lime silicates grade into and alternate with non-calcareous mica schists, some of which contain garnet and staurolite. Foliation dips to the west at 20 to 40 degrees. The structure in general appears simple, but local tight minor folds and lenses of one type of schist in another are indications of complex flowage and folding, only the broader features of which are known from regional studies (*see* p. 23).

The veins and fractures that are mineralized on the average strike east and dip 70 degrees to the south, but they are segmented and branching so that parts of veins range from north 70 degrees east to south 40 degrees east in strike and from vertical to 55 degrees south in dip. Also some veins followed toward the northwest curve northward into the foliation. The attitude of 27 mineralized fractures north of the mouth of Woodbury Creek are plotted on Figure 32. Several fractures have offset the layers so that they appear to have been faulted down on the south. One of the veins follows the wall of a lamprophyre dyke, and the two or three dykes noted in the area are in the same set of fractures as the veins.

The sulphides are in veins or replacement of the schists adjacent to veins or fractures. The veins contain quartz, calcite, and locally siderite or fluorite with clusters or bands of galena, pyrite, sphalerite, chalcopyrite, and rarely arsenopyrite.

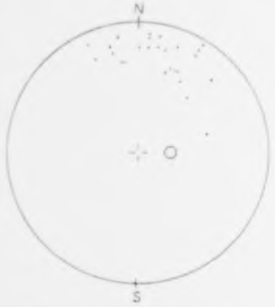


Figure 32. Diagram showing the attitudes of mineralized fractures in lower Woodbury Creek. Lower hemisphere stereographic projection. The open circle gives the average attitude of the foliation.

Both the sulphides and the gangue minerals are commonly in well-formed crystals that line vugs or show crustified or comb structures when the vein is broken. The replacement sulphides are fine grained and contain abundant pyrrhotite in association with chlorite and locally knebelite. Replacement extends laterally a foot or two from fractures that contain sulphides with or without gangue minerals. Calcareous layers in the wallrocks appear to be most favourable for replacement, and they control the attitude of the oreshoots. Replacement is also favoured by closely spaced fractures so that points where veins split or fray also control the distribution of oreshoots.

On the Vigilant two adits collared 16 feet apart just above the level of Woodbury Creek follow two steeply dipping quartz veins in an easterly direction. The veins join and the adits come together in about 40 feet; the combined zone has been followed a total distance from the portals of 280 feet. The vein contains quartz as much as 4 feet wide, but in places is merely a fracture containing strands of quartz and erratic sulphides. Replacement by sulphides occurs at the split in the vein in a layer of calcareous schist about 15 feet thick which appears to be more favourable than other layers, although it differs very little in appearance from unmineralized schist. Replacement extends a foot or two from the quartz and consequently is of greatest extent in the angle between branches of the vein. Ore has been stoped for more than 100 feet above this level, and the shoot is reported to have raked to the west with the dip of the layers.

The Vigilant vein is found on the west side of Woodbury Creek at creek level, but does not appear to extend far up the cliff above the creek. It has been traced intermittently eastward up the dip of the calcareous layers to the ridge overlooking Kootenay Lake, and from this area some ore has been shipped.

Other veins like the Vigilant are found to the south and have been followed in several short workings. The thickest are in the Amazon, No. 3 adit (*see* Fig. 31), and on the Noah claim on the highway south of Woodbury Creek. These veins are less than 2 feet thick and contain scattered pods of sulphides as well as quartz, calcite, and fluorite with little or no replacement mineralization.

Fractures in which replacement is dominant are found on the Amazon and on the August and Nameless Fractions. On the Amazon six or seven fractures with lenses of replacement sulphides up to a foot wide are exposed on the west wall of the canyon in a distance of a few hundred feet south of No. 2 adit. One or two of them are exposed in the Woodbury adit, where they consist of a tight fracture containing sulphides a fraction of an inch wide with replacement extending an inch or so into the schist on either side.

On Kootenay Lake three veins have been worked, the A vein on the Amazon and the B and C veins on the Nameless property. Apart from sulphides in quartz veins, the ore consists of a replacement of schist by sulphides. The rock most easily replaced is a soft brownish calcareous schist which near the orebodies is greenish due to the alteration of biotite to chlorite. It is replaced as a rule only to a distance of 2 to 3 feet from a quartz vein or from a fracture. The best showing is on the B vein, which ranges from 1 to 18 inches wide. Replacement of the walls principally on the north or footwall side of the vein makes an ore zone locally 8 to 10 feet wide. The best ore section began about 20 feet from the portal of the B adit, and stoping has been done above and below the level. The ore appears to have raked to the west down the dip of the layers, but very little is exposed in the rock face above the adit portal.

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Plate I. Southern part of the Ainsworth-Kaslo area looking south along Kootenay Lake. Mile Point and the Highlander mill right centre; hills and trees in the foreground are within the map-area.

Plate II. Kaslo, right centre, and Kootenay Lake from the southwest.

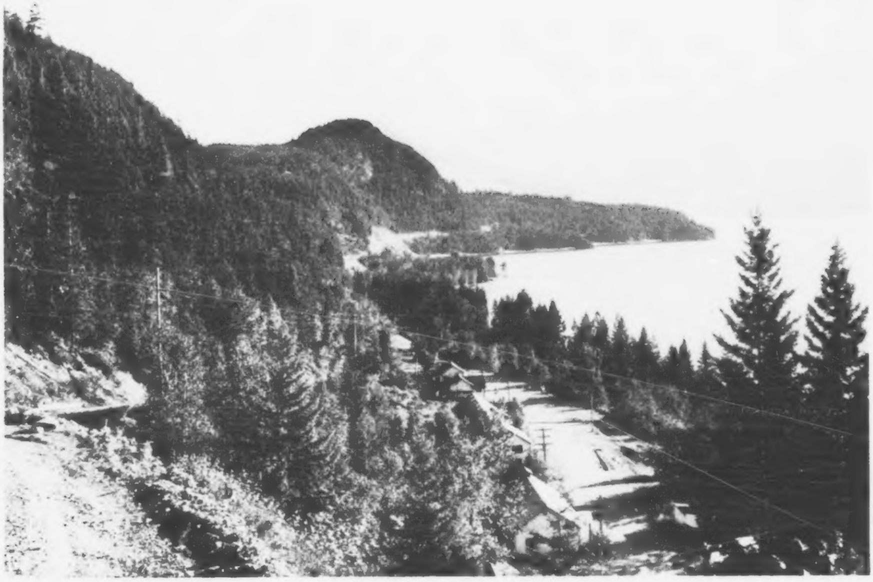

Plate III. Florence townsite looking northward to Woodbury Point.

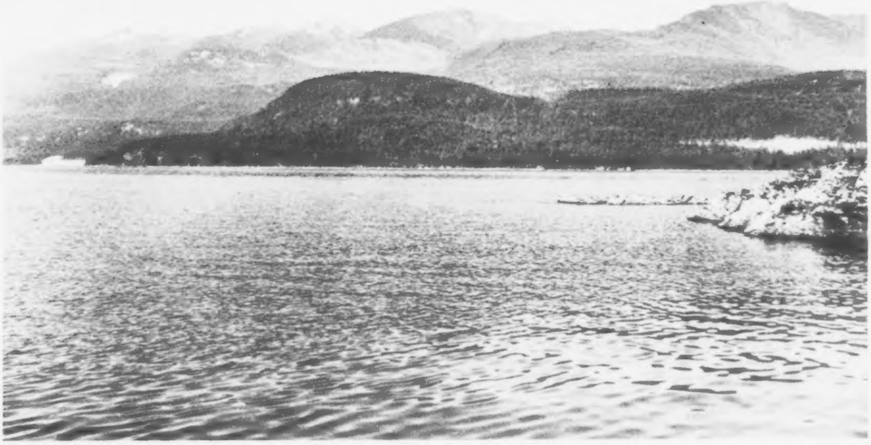

Plate IV. Woodbury Point and the Ainsworth area looking southwest from the east side of Kootenay Lake. Lendrum and Cedar Creek valleys form depressions in the skyline near centre of photograph.

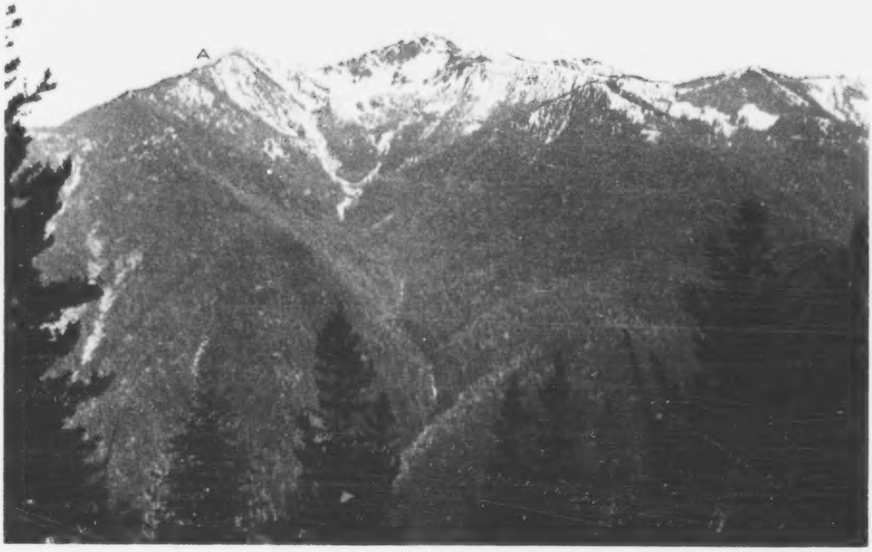

Plate V. Milford Peak looking south from the north side of Schroeder Creek. Point A is at the base of the Milford Group, east of which are grits and quartzites of the Broadview Group and west to the summit limestones, slates, and cherts. West of the summit are cherts, slates, and some green volcanic rocks.

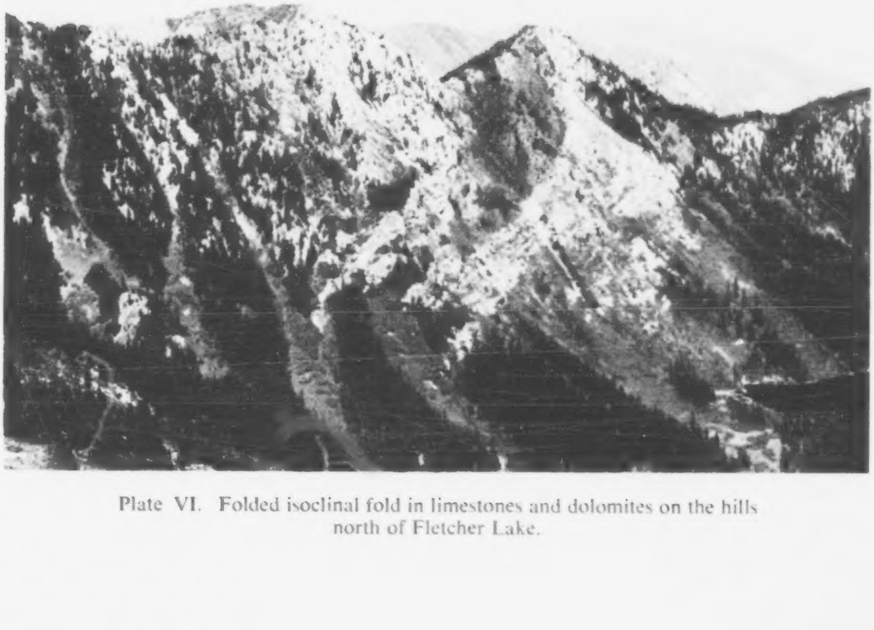

Plate VI. Folded isoclinal fold in limestones and dolomites on the hills north of Fletcher Lake.

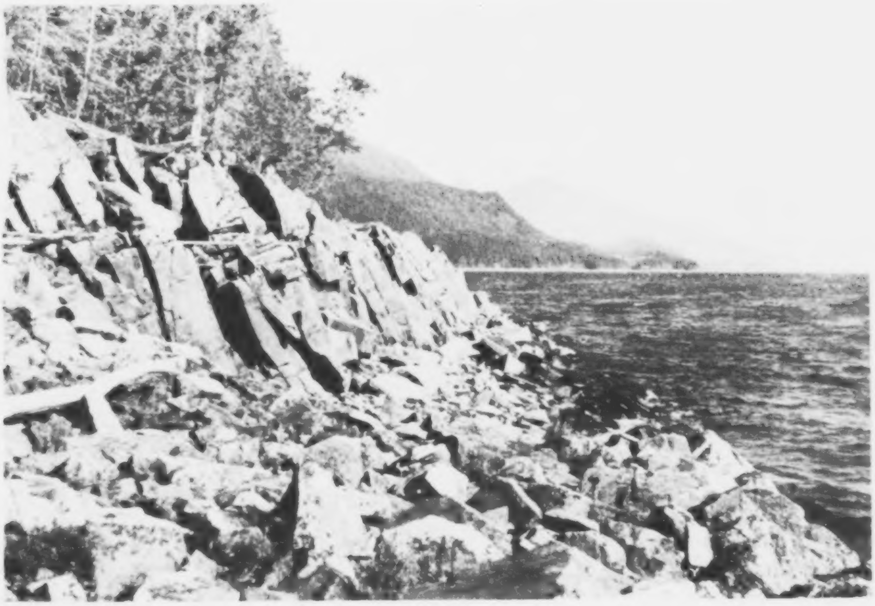

Plate VII. Blocky sills of fine-grained granites on the northern shore of Woodbury Point.

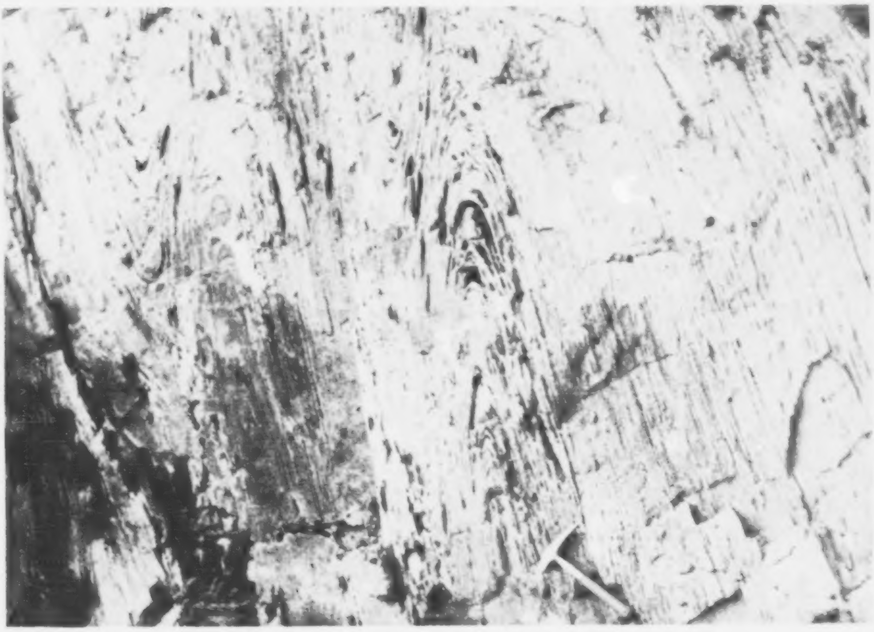

Plate VIII. Isoclinal folds, Phase I, in cherty slates of the fourth fault slice, north side of Cedar Creek looking northward along the fold axes.

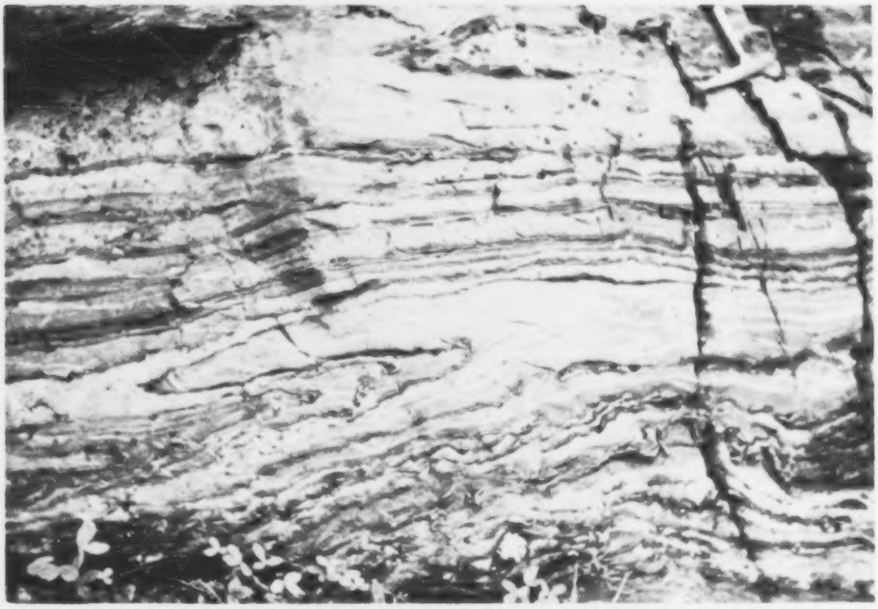

Plate IX. Isoclinally folded limestones in the fourth fault slice, north side of Woodbury Creek.

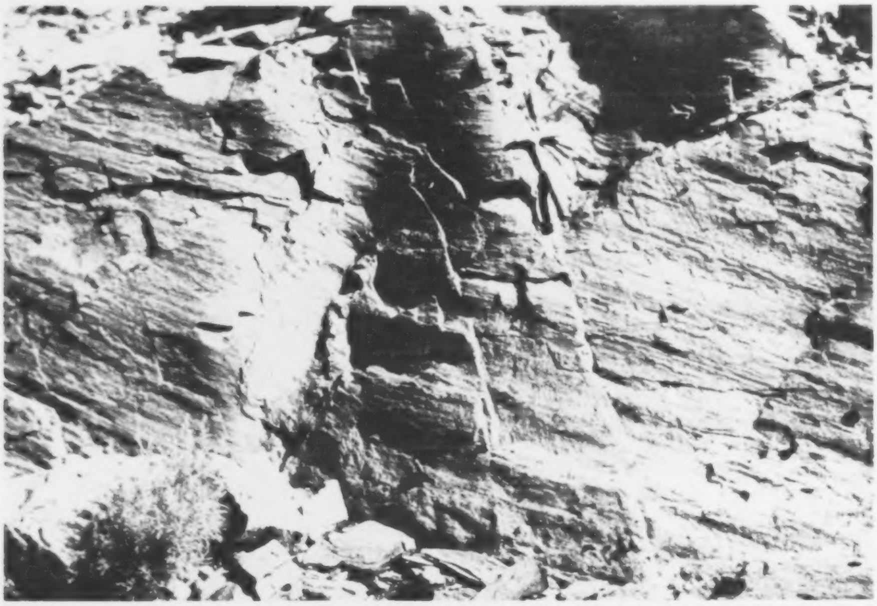

Plate X. Lineations with a low plunge warped across boudinage plunging westward down the dip of the foliation. The rocks are garnet-mica schists adjacent to a narrow granitic sill on the north shore of Woodbury Point.

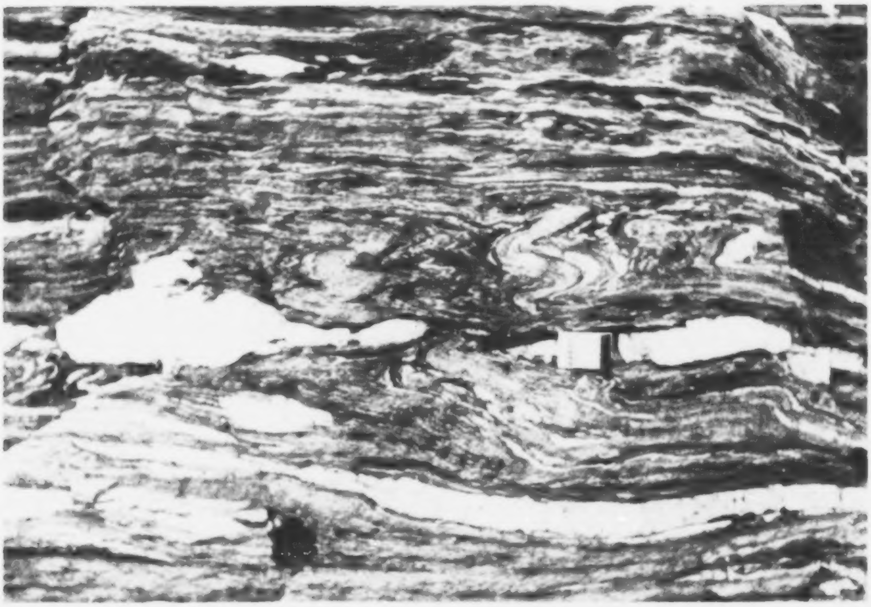

Plate XI. Contorted garnet-mica schists of the Princess Formation containing quartz-feldspar lenses, Mile Point.

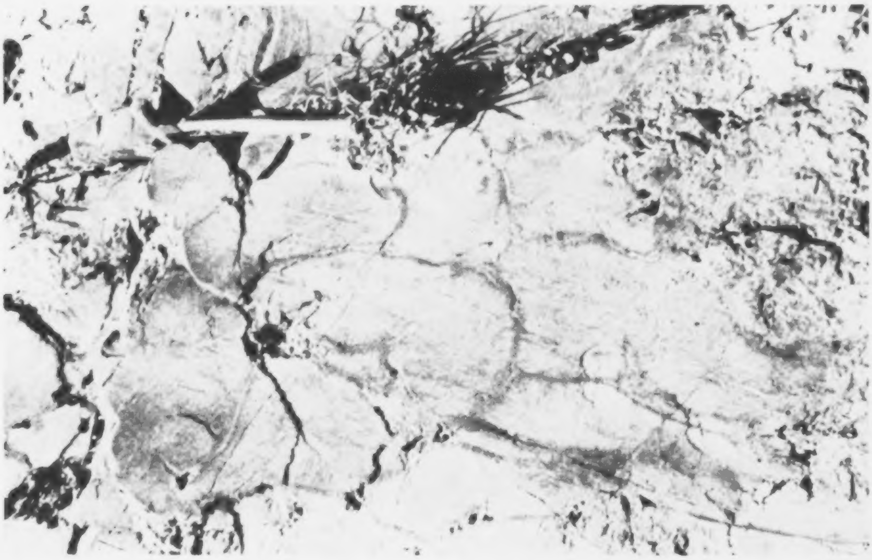

Plate XII. Pillow structure in Kaslo greenstones 1 mile south of Buchanan forest lookout.

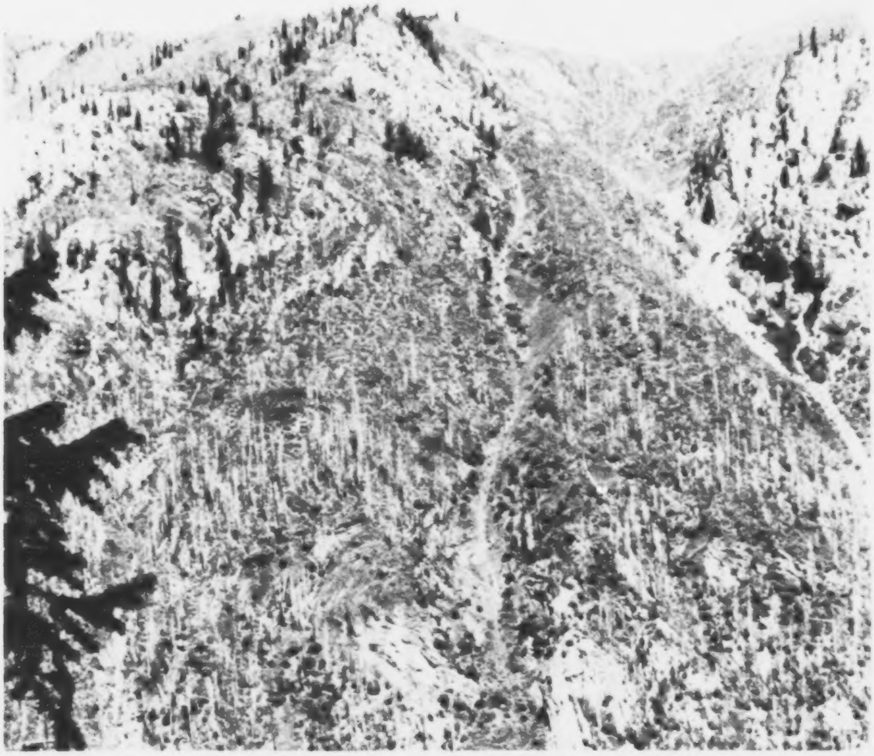

Plate XIII. Phase II folds, in dolomite and limestone, north side of Bjerkness Creek looking northward along the fold axes.

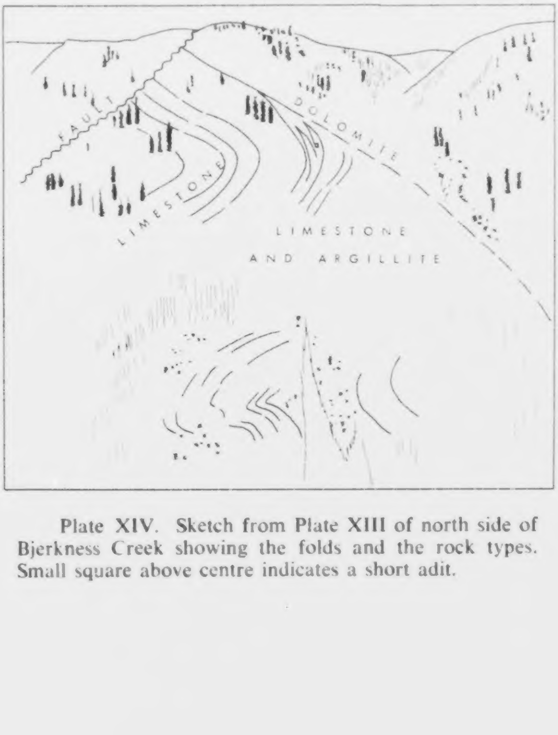
FAULT
DOLOMITE
LIMESTONE
LIMESTONE
AND ARGILLITE

Plate XIV. Sketch from Plate XIII of north side of Bjerkness Creek showing the folds and the rock types. Small square above centre indicates a short adit.

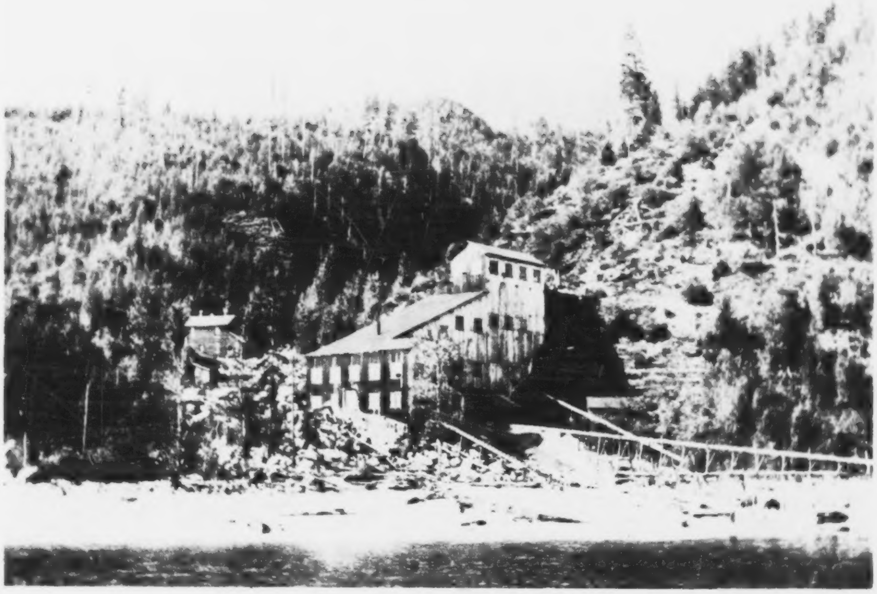

Plate XV. Highland mill, mouth of Cedar Creek, 1909.

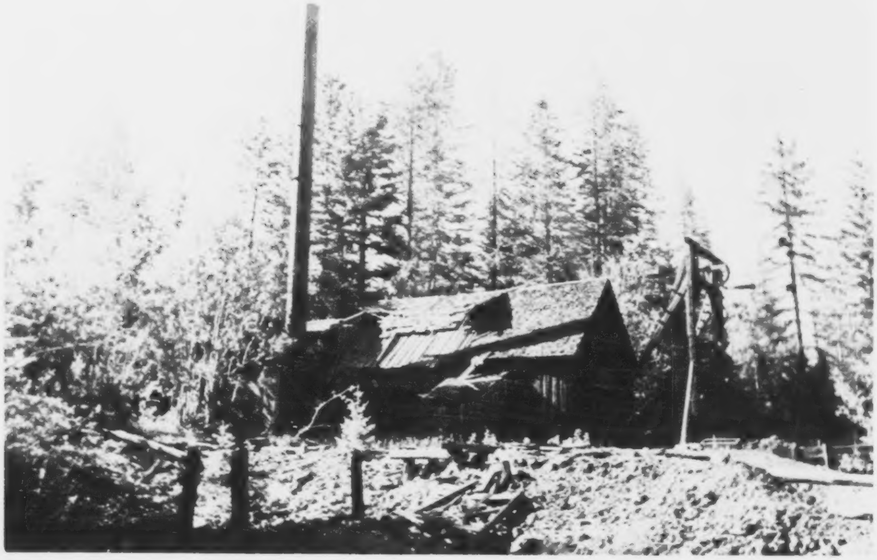

Plate XVI. Boiler-house and headframe, United mine, 1943.

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